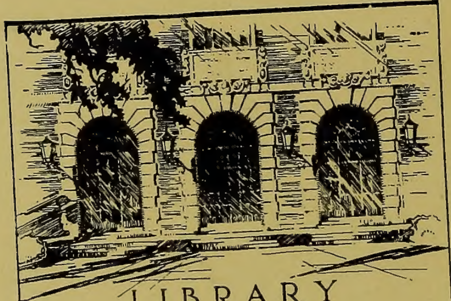

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GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

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PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Physical Aspects of Machine Construction

1.1 Shop

Construction by the shop during January has been primarily for the main arithmetic unit, flow-gating and two test control chassis.

The following list shows construction of the new machine as of January 31, 1961:

Chassis Completed

QRM ------ No. 1, 2, 3
$QRM\text{-}D^2$ --- No. 1, 2 (Driver Drivers for QRM)
A -------- No. 1, 2, 4, 5
$AS\text{-}D^2$ ---- No. 1, 2, 4 (Driver Drivers for A,S)
S -------- No. 1, 2, 3
FF_c ------ No. 1 (Flow-gating)

Chassis (Completed with Exception of Diodes)

QRM ------ No. 4, 5, 6, 7, 8, 9, 10
$QRM\text{-}D^2$ --- No. 3, 4, 5
A -------- No. 3, 6, 7, 8, 9, 10, 11, 12, 13
$AS\text{-}D^2$ ---- No. 3, 5
S -------- No. 4, 5, 6, 7, 8, 9, 10, 11, 12
FF_c ------ No. 2, 3
FF_d ------ No. 1, 2
Test Control II

Under Construction

QRM ------ No. 11

Test Control I

Cycle Timer for Core Memory

FF_d ------ No. 3, 4

FF_c ------ No. 4

1.2 Small Parts

The small parts referred to in the December monthly report are being received. Orders for parts A-2001, A-2002 and A-2004 are complete. The B-2003 (terminal strip order) is presently being filled with partial shipments. Production of heat sink A-2005 is now underway.

1.3 Main Computer Frame

The order for the frame is now in the hands of the manufacturers.

1.4 Computer Air Conditioning

The plans for the air conditioning were checked and revisions were requested to provide for more primary power in the power supply room.

(C. E. Carter, T. E. Kerkering and Shop)

1.5 Drawings Completed During January

New Machine Drawings

Revised and Completed

D-966 - QRM

C-967 - QRM Logic

B-972 - A_{2C} (Carry Generator Logic)

C-973 - A_{4C} (Carry Generator)

B-974 - A_{4C} (Carry Generator Logic)

D-993 -

D-994 - Flow-Gating

D-996 -

D-997 -

C-979 - A_{1F-5F} A_{1R-4R} Logic

C-981 - S^*_{40-44} Logic

Completed

C-1072 - Chassis Nomenclature

C-1005 - S_{-3}-S_0 Logic

D-968 - QRM_{4C} (R and Q Zero Detect)

C-1001 - A^*_{-2}-A_0 Logic

C-1023 - QRM_{41-44} Logic

Pencil Drawings Completed

D-1000 - A^*_{-2}-A_0

C-1009 - QRM $(M_{-1,0})$ $(R^*_{-1,0})$ $(Q_{-1,0})$ Logic

(C. E. Carter, S. P. Krabbe, H. E. Lopeman, Drafting)

2. Design of Arithmetic Control

A preliminary logical design and drawing has been made for every portion of arithmetic control, using the new and faster design rules.

Hideo Aiso designed

1. Add to exponent type orders
2. Clear add type orders
3. Store orders
4. Right shift orders

Michael Faiman designed

5. Normalize
6. Additional logic for the decoder at the output of the exponent adder

John Penhollow designed

7. Divide
8. Floating point add
9. Correct overflow and detect zero
10. Many of the interconnections between sequences, and the incorporation of normalize.

Richard Shively designed

11. Multiply
12. Decode.

Robert Swartwout designed

13. The 6 selector controls for the MAU
14. The 3 selector controls for the EAU.

Various errors were corrected in the flow charts, and improvements made. There remains the problem of carefully checking the entire control and of ensuring that the flow charts, as modified, are correct, and that the controls and arithmetic unit logic has been made to correspond. This checking is well under way.

Following completion of the aforementioned preliminary logical diagrams, a transistor and logical element count was made to use in the layout of the control and in material procurement. The estimate of December 1, 1960 was 6300 transistors whereas the actual count from these preliminary diagrams was 6200. Since final checking, level shift analysis and inclusion of interlocks will probably add transistors, it would appear that the figure of 6300 was rather close. The actual figures obtained are given below, together with the code letter assigned to each arithmetic control subsequence. Each control point within the control will be designated by this code letter plus its number within the subsequence. It is felt that these designations will simplify the tagging of wires interconnecting two subsequences.

Section of Arithmetic Control	Transistors Required	Sequence Code Letter
Floating Add	637	A
Clear Add	131	B
Division	772	D
Exponent Arithmetic	56	E
Shift	323	F
Decode Next Instruction	517	G
Correct Overflow and Detect Zero	205	K
Load Q	92	L
Multiply	249	M
Store Preliminaries	84	P
Normalize	216	N
Store	424	S
Difference Absolute Value	133	V
TOTAL FOR SEQUENCING	3839	
Exponent Arithmetic Unit	970	
MAU Selector Controls	877	
EAU Selector Controls	280	
MAU and EAU Gates	242	
TOTAL FOR ARITHMETIC CONTROL	6208	

2.1 Control Design Rules

The time per step in sequencing control has been reduced by causing the turnover of an Eccles-Jordan memory element to occur in parallel with the operation of any gates, selectors, memory elements required in the step. The suggestion was due to R. Shively.

A second modification had to be made to maintain speed independence when the conditional operation of a gate, selector, or memory element was required. Formerly it was felt that the replies in such cases could be by-passed at each control point, however it was found that only one by-pass point for each gate, selector, or memory element was permissible. This necessitated that for each conditional operation, a conditional signal and its complement (called the by-pass), be formed and that the control logic for the gates and selectors be revised to accept these by-pass signals.

(R. E. Swartwout)

The two step iterative loops in floating addition and in shift have been designed in such a way that when no changes in selector settings are required, such as for long shifts preceding addition, the large numbers of conditional operations are completely by-passed, and the loop operates at the speed of a loop without such conditional operations.

(J. O. Penhollow)

2.2 Level Shift Calculations

Specifications were prepared for an Illiac program whose function is to calculate level shifts in any logical configuration. The program was written and checked by J. N. Snyder and uses the level shift curves of File No. 343. It has been successfully used to check out the logical circuitry of the E-adder. As a result, a close examination was made of File No. 343. Some assumptions about resistor values and load currents that are made therein do not obtain in practice. To reformulate such curves, as for example might be dictated by a change in any of the circuit parameters, would be a costly and time-consuming process. It was therefore decided to examine the tolerance analysis procedures for the three types of non-restoring circuit with a view to establishing a computational method that would be the same for the three types and could be handled by a computer. Such a method was indeed found.

(M. Faiman)

2.3 Advanced Control

A register arrangement for advanced control has been decided upon, and the details of its operations are being studied.

(D. B. Gillies, C. Wallace)

3. Paper Tape

3.1 Paper Tape Editing Equipment

No manufacturer submitted a bid on the paper tape-editing equipment. New bids have been called for, closing February 16. The request for new bids includes an additional typewriter and tape reader.

3.2 Paper Tape Reader

The Coordinated Science Laboratory has been furnished with an outline of the logical arrangement of reader and punch control signals, and is beginning logical design. The Elliot 1000 cps reader demonstration set has been badly damaged. There is no Elliot reader being run at 1000 cps in the country, but two readers are available from stock. It seems likely that a 1000 cps system can be obtained for study within the next two months. The following possibilities are being explored by the Coordinated Science Laboratory.

a) Try to get a reader on approval for a couple of weeks.

b) Try to find out whether any Digitronics reader, running at 1000 cps, is available for demonstration to us.

(C. S. Wallace)

4. Interplay

A preliminary look at the problem of organizing many simultaneous block transfers in a manner such that speed does not affect the course of a program, and which is easy for the programmer to use, suggests strongly that the problem is not soluble with a reasonable amount of automatic hardware. However, if all transfers are organized by a routine, which the programmer may enter to initiate transfers, there seem to be acceptable solutions. In this case, i/0 controlling orders would appear only in this routine and possibly in monitoring interruption routines.

(C. S. Wallace)

5. Core Storage Unit

During this month, the model memory was operated with 4 bits and 64 words in use. Under the condition of 1.6 µs cycle time and a 1010... pattern stored, the memory operated error free (as indicated by single-error detection circuitry) for 170 hours at which time it was voluntarily stopped. Power supply failures were responsible for the termination of several later attempts to obtain a long run.

(S. R. Ray)

The layout for the address decoders has essentially been completed.

A test circuit capable of logging parity-check errors, resetting and restarting the memory has been designed and built.

(B. E. Briley)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

R. Crow has made a series of measurements on the transient base-currents in the case of very fast rising or falling signals. H. Guckel has investigated transistor behavior at very low impedance levels and C. Afuso has examined the behavior of switching amplifiers more in detail. All these projects are needed in order to obtain a basis for the design of a milli-microsecond shifting register as described in the December report.

2. Transient Base Currents

Efforts have been directed toward measurement of the transient base current in the circuit shown in Figure 1.

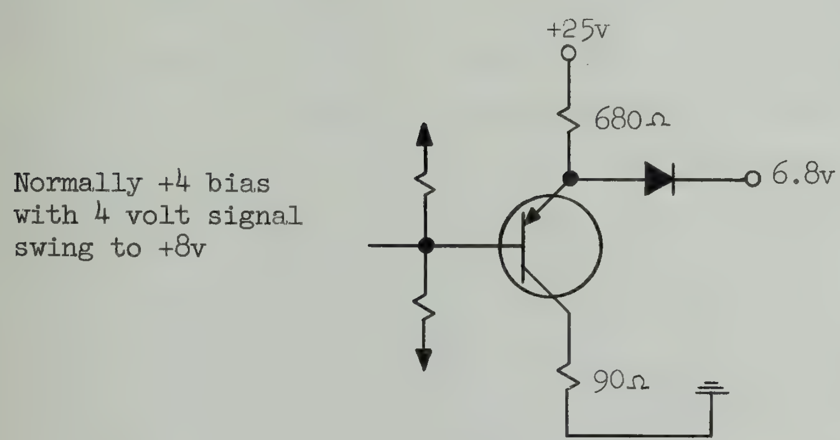


Figure 1
Transient Base Current Measurement Circuit

The first method used for the measurement is indicated in Figure 2. The input was a 47 mμsec, 4 volt positive pulse. Photographs were taken of

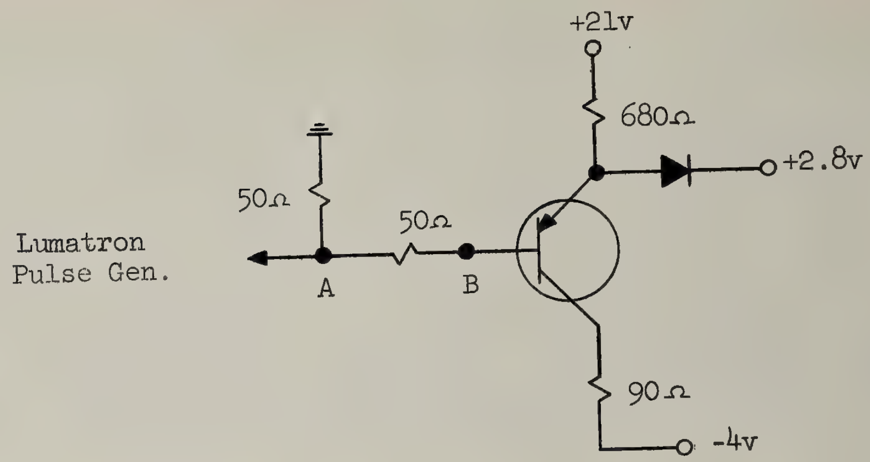
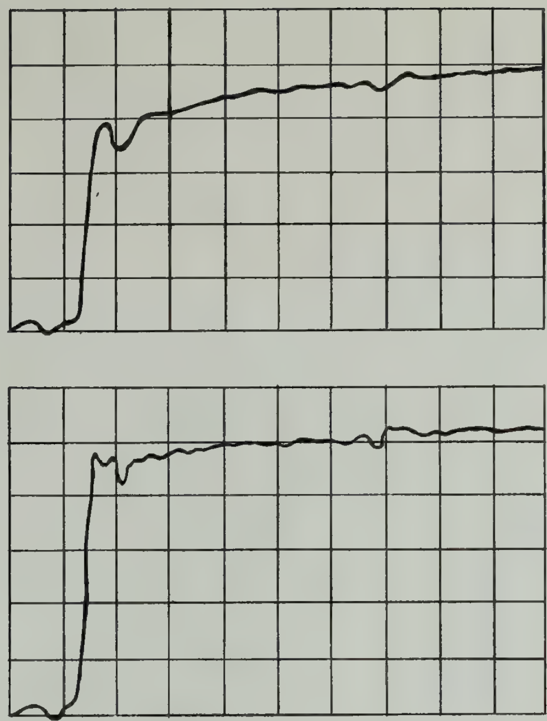


Figure 2

Improved Circuit for Transient Base Current Measurements

the voltage at points A and B. The difference of the voltage at A and B, divided by 50Ω is the base current. Figure 3 shows the turn-off voltages, and Figure 4 the turn-on voltages. Base currents calculated from the pictures are shown on Figure 5. The main disadvantage of this method is the inaccuracy due to differencing two voltages which are close together in magnitude. Another disadvantage is that the net base driving impedance is 100 ohms. Measurements with lower base drive impedances are desirable. The biases in Figure 2 were shifted to allow the 50Ω termination of the pulser to be at ground potential. The advantage of this method is that the drive pulse is relatively clean with fast rise time. In the other method to be described, a fast rise time pulse (0.3 mμsec) presented problems of ringing and overshoot.

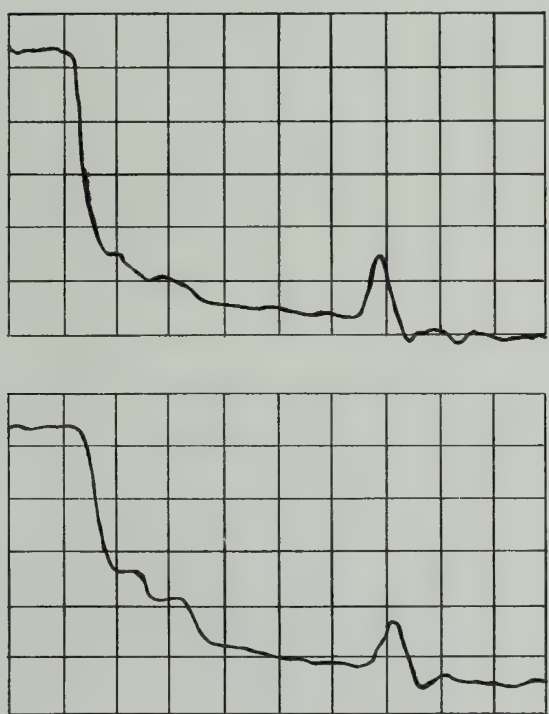


Point B 5.4 cm = 4v
2 mμsec/cm

Point A 5.4 cm = 4v
2 mμsec/cm

Figure 3

Turn-Off Voltages



Point A 5.4 cm = 4v
2 mμsec/cm

Point B 5.4 cm = 4v
2 mμsec/cm

Figure 4

Turn-On Voltages

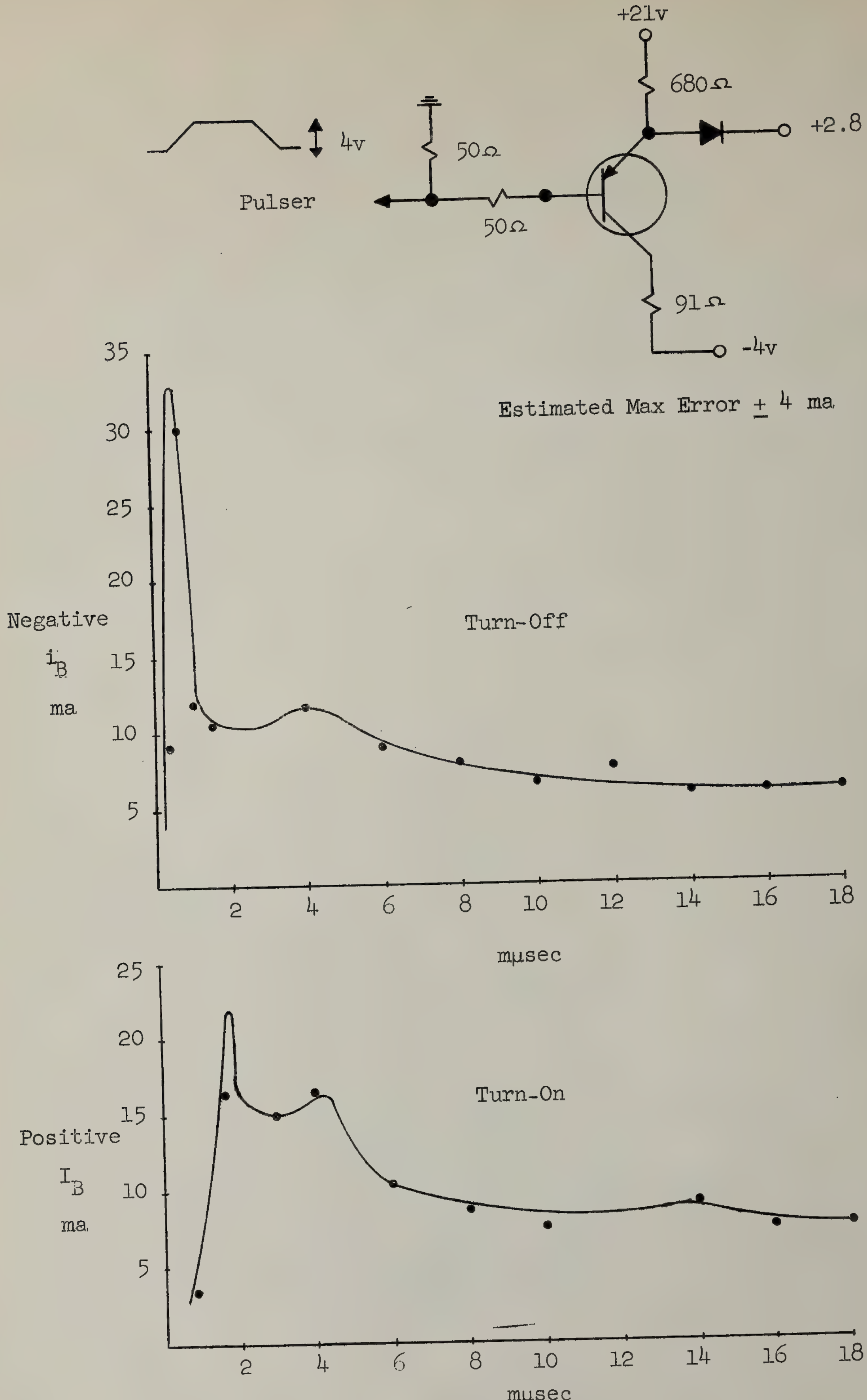


Figure 5

Circuit and Observed Base Currents

In an effort to eliminate the voltage differencing problem an emitter drive circuit, shown in Figure 6 was used. In this circuit

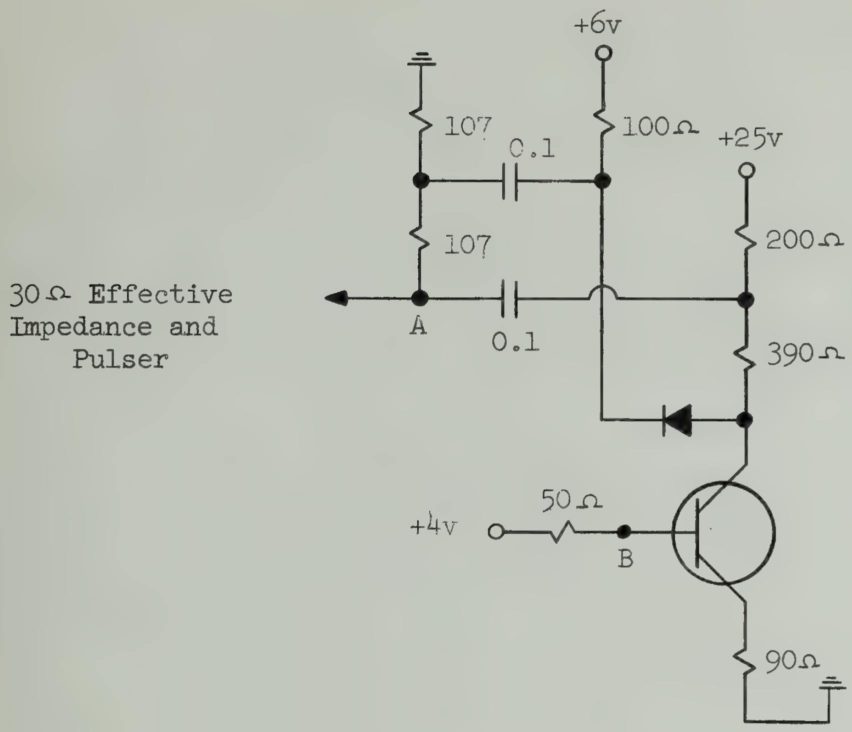


Figure 6
Emitter Drive Circuit

the switching is done from the emitter and the base voltage is a direct measure of the base current, if the 4v bias supply is properly filtered. The voltage divider to the cathode of the diode is necessary in order to switch the current. With no input the transistor is on and the diode off. To turn the transistor off a negative pulse is required at A. In this measurement, a 3v negative signal swing at the emitter was used. In order to switch the current into the diode, the cathode of the diode must swing at least as far as the emitter, plus the original back bias on the diode, plus the on voltage drop of the diode.

Difficulty with overshoot and ringing at A with a 0.3 mμsec rise time pulse has so far not been overcome. In order to get a reasonably

clean pulse at A, the pulse from generators was filtered to give a rise time of approximately 3mμsec. Figure 7a shows the drive pulse. Figure

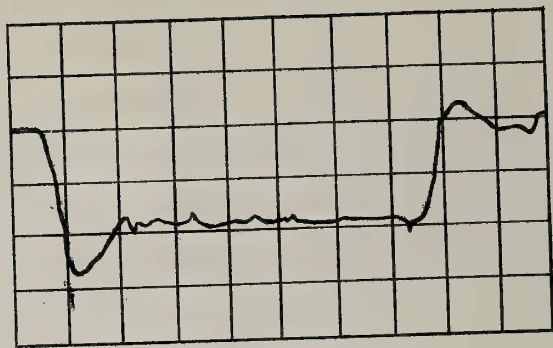


Figure 7a
7 v/cm 5 mμsec/cm
Drive Pulse at Point A Figure 6.

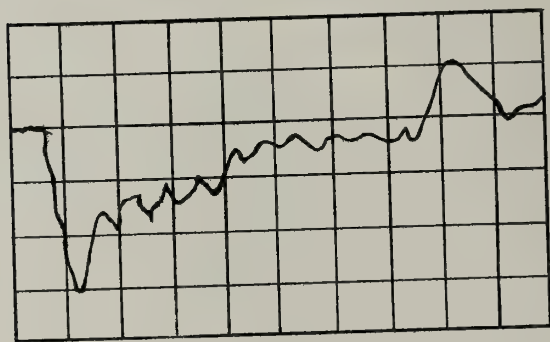


Figure 7b
11 ma/cm 5 mμsec/cm
Voltage at Point B Figure 6

7b shows the transient current of a typical GF45011. It is hoped that the technique of Figure 6 can be improved using better layout and low inductance resistors so that a faster rise time pulse can be used. This method has the advantage that the current waveform can be observed directly, and the base drive impedance could be reduced to as low as 10 ohms practically. More work is anticipated on this method.

3. Transients in Transistors at Low Impedance Levels

Emphasis has been on a study of transistor behavior as impedance levels of less than 100 ohms in the collector. The points of interest are:

1. Device Behavior:

The problem here may be split into two parts. The first one concerns itself with the optimum or maximum allowable current density to be switched, while at the same time maintaining a given rise time. Power dissipation is only a minor consideration. It is found that, regardless of saturation margin, currents in excess of $\sim$14 ma for the 45011 will not be beneficial due to sharp switching time decreases. The second point is concerned with the amplitude of the switching signal. It is found that voltage overdrive results in considerable ringing in the collector circuit. This in itself is a major problem since the existence or non-existence of ringing could be controlled by changing input amplitudes by as little as .2 volts, i.e. by a value easily obtained under normal tolerance conditions. A third point, mentioned in a previous report, is that of the relaxation time of the device. A fairly good idea of what magnitudes are involved is obtained by using the test indicated in Figure 8.

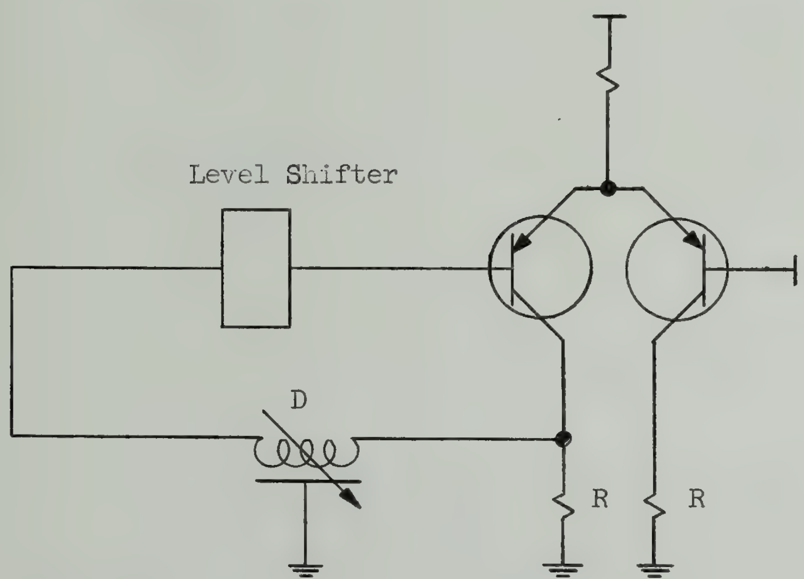


Figure 8
Emitter Settling Time Set-Up

D is adjusted until oscillations result. These are on-off type oscillations, i.e. not a normal amplifier-type, and yield a good value for the emitter settling time. From this type of data it becomes apparent that a fast set of circuits will possibly be repetition rate limited. This should be considered now before too much time is wasted on fixed topologies and layouts.

2. Layout:

It is believed that a fairly good layout may be obtained by using the scheme in Figure 9.

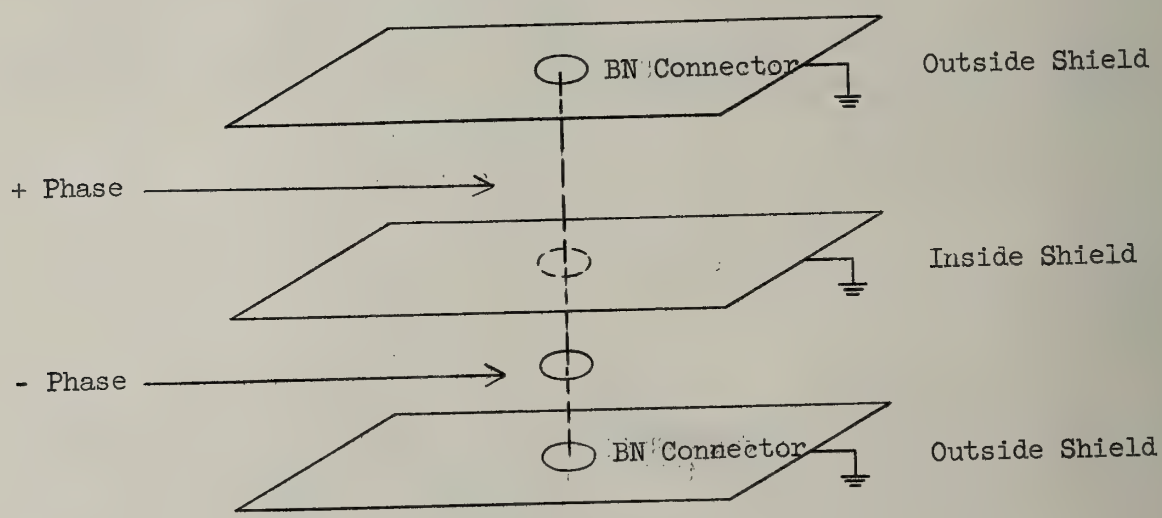


Figure 9
Shielded Circuit Layout

Triple ground planes are used to obtain shielding towards the outside and shielding between + and - phase components in the individual circuits. The circuits themselves are organized in layers parallel to the reference planes. Symmetrical layouts are used as demonstrated by the emitter circuit (See Figure 10). Transistor sockets were not used.

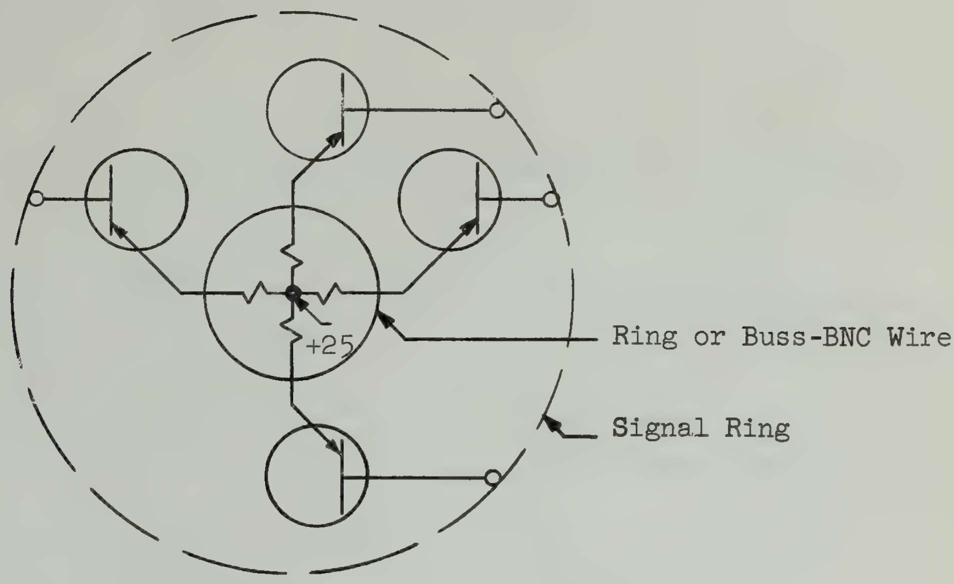


Figure 10
Emitter Circuit

4. <u>Fast Switching Amplifiers</u>

Switching times vs emitter current levels, input amplitude and impedance level are being studied. It seems feasible to produce rise and fall times of less than 1 mμs with 2 v input signals at a current level of about 12 ma. Complete results will be discussed in next month's report.

PART III

MATHEMATICAL METHODS

<u>Numerical Evaluation of Functional Integrals</u> (Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Studies in the evaluation of path integrals are continuing. These integrals arise in a wide range of fundamental problems in physics; see the following review article on this subject: S. G. Brush, Revs. Modern Phys. <u>33</u>,79 (1961). Following a technique proposed by Cameron (R. H. Cameron, Duke Math. J. <u>18</u>, 111 (1951)) the numerical evaluation of the Wiener integral

$$I = \int_{C} F[x]\, d_x x ,$$

where

$$F[x] = \exp\left\{ - \int_0^1\!\!\int_0^1 t\, t' x(t)\, x(t')\, dt\, dt' \right\} ,$$

has been executed. This integral can be calculated analytically, thus providing an exact evaluation of the error in the numerical calculation. The numerical calculation involves parameterizing the paths by expansions along an orthonormal set $\phi_i(t)$

$$x(t) = \sum_i \xi_i\, \phi_i(t) ,$$

and the sampling of the paths is reduced to a sampling of values for ξ_i. The sampling of the ξ_i's is not uniform but modified so that attention is focused on the "important" paths. The results of this computation were in good agreement with the analytical result and the spread in the Monte Carlo estimate was in good agreement with the theoretically predicted spread.

The details of this computation will appear in the Digital Computer Laboratory, File No. 361.

(L. D. Fosdick)

<u>Progress Report on Editing John von Neumann's Manuscripts on the Theory of Automata</u> (Supported in part by the National Science Foundation under Grant G9503.)

The work will probably be entitled <u>The Theory of Complicated Automata</u>. It will contain

I. Introduction (by myself)
   - A. Outline of von Neumann's theory of automata.
   - B. Summary of Part III.
   - C. Sketch of how to complete Part III.

II. Theory and Organization of Complicated Automata (Strongly edited version of von Neumann's Illinois lectures.)

III. Theory of Automata: Construction, Reproduction and Homogeneity (Slightly edited version of an incomplete manuscript left by von Neumann.)

I have studied the Illinois lectures (II) very carefully and collated them with all von Neumann's materials (published and unpublished) on automata theory. Part A of the introduction will contain background material for these lectures; I am ready for the detailed editing of the lectures as soon as this part of the introduction has been written.

I have worked through the manuscript (III) in considerable detail. This manuscript carries the construction through the tape unit. It is correct in principle as far as it goes. There are some minor errors. On page 94 of Ch. 3 von Neumann miscalculates the size of an organ; correction of this entails some change of the layout of the tube control. I have prepared a rough-draft summary (with about 25 figures) of this manuscript.

I have consulted a number of people who worked with von Neumann and I have done other work in preparation for writing Part A of the introduction.

(Arthur W. Burks)

PART IV

DATA REDUCTION METHODS

(Supported in part by the National Science Foundation Under Grant G9503)

AUTOMATIC REDUCTION OF DATA FROM BUBBLE CHAMBER PHOTOGRAPHS

Work is being carried on in three directions. The tracking routine described more fully in the October report has been modified so as to continually monitor the quality of the tracking as the tracks under consideration are being followed. Certain functions which describe this quality, such as dispersion from the actual track, amount of track missed, etc., are printed out for each track. The larger sample of tracks referred to in the December report are being subjected to this process.

This larger sample of tracks is also being processed by the Illiac programs described in the November report, in order to see whether or not the processes there described are efficient in seeking out uncluttered initiation points on each track.

A set of specifications is being formulated for an input-output oscilloscope to be attached to Illiac. This oscilloscope can be imaged on a photographic negative and by means of a photo sensing device will enable Illiac to digitally encode and input photographic material. In principle, this equipment will act as a high speed random access fixed photographic memory with a resolution of 1024 x 1024 bits.

(K. E. Hillstrom, M. Kuchnir, B. H. McCormick, and J. N. Snyder)

PART V

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of January, one new routine was added to the Illiac Library.

RA2 - 315 Square Root Auxiliary for Routine A7, Floating Decimal Arithmetic Routine (DOI or SADOI). This is a double precision square root routine designed for use with Library Routine A7, "1.7 Precision Floating Binary Arithmetic and Double Precision Arithmetic with Floating Decimal Conversion (DOI or SADOI)".

(John Ehrman)

Illiac Usage

During the month of January, specifications were presented for 26 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 1846T. Numbers followed by T are for theses.

1846T Chemistry. Configuration Coupling. This research is an investigation of the effect of structural features on magnitude of the spin - spin coupling and chemical shift in rigid ring systems; specifically, 4 phenyl $2_1 6$ dibromo cyclo hexanone. The program that is to be used is the same one employed for Illiac Problem Number 1202T.

1847 Mechanical Engineering. Investigation of Rope Failures. The investigation requires the solution of a cubic equation with variable coefficients. Thus, with the use of the library routine for solving algebraic equations, and a program to compute the coefficients, a solution to many rope problems is easily obtained.

1848 Theoretical and Applied Mechanics. Two Point Mass on a Beam. The problem is to determine the deflections of a beam supported by two flexible springs. On this beam moves a rigid mass which has two points of contact and is moving under known conditions of acceleration.

The solution has been reduced to two Voltera type integrals which must be solved by an iteration technique similar to the Trapezoidal Rule for integration.

1849 Institute for Research on Exceptional Children. Relationship Between Three Components of an Index of Marital Integration and Three Parent-Child Communication Indices. The Illiac will be used to obtain multiple correlation coefficients between three components of an index of marital integration of husband and wife (independent variables) and three parent-child communication indices (dependent variables); one set of indices is for father-child communication and an identical set for mother-child communication.

The sample consists of both parents and one child in 106 families. There are 51 families with a male child represented and 55 families with a female child.

Illiac routine K-16 will be used to obtain multiple r's between components of the index of marital integration and each dependent variable for families with a male child only, families with a female child only, and for all families combined.

1850T Speech--Hearing Center. Factorial Study of Bone Conduction. This is a factorial study of one method of testing hearing--the method of bone conduction. Experimental design is a Latin Square Split Plot. There will be 23 analyses of variance run, the largest with 5200 degrees of freedom (5200 units of observation).

1851T Electrical Engineering. Submillimeter Wave Generation Using Cerenkov Radiation. Maxwell's equations have been solved for a tensor dielectric and magnetic medium as a boundary value problem where the geometry is that of a concentric cylinder. The experiment for which this computation is being

done involves an electron beam moving along the axis of a plasma cylinder which in turn is surrounded by an infinite dielectric. An axial magnetic field is imposed on this complex.

The problem is solved analytically by matching field values at the beam-plasma and plasma-dielectric boundaries. The fields so found are then used to calculate the average submillimeter power generated by Cerenkov radiation of the beam. The form of the solution is a set of eight linear algebraic equations whose coefficients are cylinder function, i. e., Bessel, Neumann, and Hankel functions; the arguments of the cylinder functions are in general complex. To find optimum experimental design parameters, it is proposed to solve the problem by digital means for a range of values of (1) the D. C. axial magnetic field, (2) the beam radius, density and velocity, (3) plasma density, (4) pumping frequency, and (5) relative permittivity of the dielectric.

1852T Mechanical Engineering. Processing of Experimental Data Obtained for the Development of Boundary Layers. The experimental data is obtained in the form of velocity profiles at various stations along a flat plate which has a roughness element attached to it. By using library routine E4-193, the first and second derivatives of the velocity profiles can be obtained from which the shear stress and the total energy dissipation can be calculated.

It is hoped that with this information, a program can be written so that by starting with an initial velocity profile and the wall shear stress distribution, the further development of the boundary layer can be determined by numerical solution of the energy and momentum equations of such a boundary layer.

1853 Physics. Stellar Evolution. This problem is a continuation of that specified in problem number 1752. The present program will perform trial integrations and perform the necessary corrections so as to converge to a physically acceptable solution; it contains several improvements derived from earlier trial runs.

1854 Agronomy. Field Planting Patterns. Field experiments involving either corn or soybeans have been designed to test some of the following differences: effect of normal and dwarf corn plant in the same hills and at different row and hill spacings; effect of planting different varieties of soybeans at different row spacings.

Analysis of variance will be used to determine if differences actually exist.

1855T Music. Probability Analysis of Music. This problem is a detailed analysis, using information theory, of an important contemporary piece of music (Webern's Symphonie, Op. 21). The information contents associated with pitches, rhythms, musical intervals and other elements will be computed. The calculations from 0th order through possibly 9th order will be made if it seems justifiable. The basic (monogram) formula is the following:

$$H_i = -\sum P_i \log_2 P_i$$

All the other formulae (for diagrams to n-grams) are derived from this one. H will be computed not only for mono- to n-grams on the basis of elements (e. g. pitch) considered apart from the other elements, but also in combination (e. g. the combination of pitch and rhythm, or of pitch, rhythm and timbre).

1856 Digital Computer Laboratory. Tolerance Analysis. The circuit analysis routines are to be used for doing a complete tolerance analysis of the "slow circuits" which will be used to build the input-output electronics for the new Illinois computer.

1857 Digital Computer Laboratory. Control Voltage Levels. The control of the new Illinois computer involves a complex of cascaded and fanned-out logical elements. The tolerances on the signal voltage levels change as a signal progresses through the various alternate routes of such a complex. It is the purpose of this program to compute and check the tolerances at various modes within such a complex circuit.

1858T Chemistry. Anchimeric Acceleration of Homolytic Bond Cleavage. The effect of certain ortho substituents upon the rate of thermal decomposition of tertiary-butyl perbenzoates is to be studied. These compounds generally follow a first-order rate law in their decompositions. The best line and hence the rate constant and standard deviation for a large number of kinetic runs will be determined by the method of least squares. The Illiac would be employed to minimize tedious manual calculation. The equation involved is:

$$-2.303 \log (x - a) = kt + c$$

A series of x and t values for about 40 runs have been determined along with 3 values of a for each run--a total of 120 lines and k values.

In another portion of this work, the following equation is used:

$$k = \left(\frac{dx}{dt}\right) \times \left(\frac{c}{p_0}\right) \qquad \text{from } x - x_0 = \frac{p_0}{c}\, t$$

About 20 runs are involved here, 20 lines, k values and standard deviations.

From these values of k, activation parameters will be determined.

1859 Psychology. Second Order Personality Factors. The basic problem under investigation is the determination of the second order personality structure which is comprehensive over both adolescence and young adulthood. This has been determined for both age groups individually but not together in a single study. The primary personality factors uncovered in a first order study are used as the basic materials. Their intercorrelations are found and the matrix is factored, using estimated communalities. Rotation to simple structure through both hand and machine methods must be done in order to determine psychologically meaningful structures. Therefore, almost all of the statistical analysis is to be done on Illiac.

1860T Physical Education for Men. "P-Technique" Factor Analysis of Cardio-Respiratory Variables. The description of cardio-respiratory condition is a complex problem since it is evident that the term involves far more than a unitary concept. This fact is evidenced by the results of eight factor analyses in this area. Furthermore, an individual may score extremely well

in some tests of this state and extremely poor in others.

All of the eight factor analyses to date have studied co-variation between individuals. In all studies but one, the test battery was very limited. Physical education is concerned with changes brought about within the individual primarily as a result of exercise. This study is concerned, therefore, with the co-variation within an individual over a period of time.

The study is an attempt to identify and describe factors associated with cardio-respiratory condition within the individual by factor analyzing 70 individuals over a period of five months of hard physical training. Included in the data are various related variables, such as hours of sleep, humidity, temperature, and barometric pressure.

1861T Civil Engineering. Analysis of Underground Arch. This problem studies the response of shallow-buried, underground arch structures to blast loading from the explosion of a nuclear weapon.

The Illiac may be used to integrate the equations of motion in order to obtain the response.

The arch has been approximated by a two-degree-of-freedom system with equations of motion as follows:

$$h''_j = F_j(\bar{H}_j - Q_j - \bar{Q}_j) + G_j(\bar{H}_i - Q_i - \bar{Q}_i)$$

where: h''_j = acceleration of concentrated mass in desired direction.

F_j, G_j = constants proportional to the natural frequency of the system in the predominant excited mode.

$\bar{H}_j$ = load concentration on mass in desired acceleration direction.

Q_j = arch resistance.

$\bar{Q}_j$ = soil resistance.

1862T Agronomy. Seedling Vigor and Emergence of Birdsfoot Trefoil as Influenced by Depth of Planting, Variety and Seed Size. Analysis of variance of number of plants, weight of tops, weight of roots, total plant weight, weight of tops per plant, weight of roots per plant, total weight per plant, and stem length for both field problem and associated greenhouse study will be

carried out. Single degree of freedom information is also desired on selected factors.

Analysis of variance will be desired on emergence for both greenhouse and field study and for vigor ratings from field data.

The problems under study are the differences in the rate of emergence and seedling vigor as related to three different factors: depth of planting, variety, and seed size in birdsfoot trefoil.

1863 Music. Fourier Analysis of Sound Waves. To establish a procedure of Fourier analysis of string tones, it is proposed to test the Illiac V4 (Fourier Analysis) Routine on both an oscilloscopic reproduction of a smooth guitar tone, and on a saw-tooth curve. By comparing the Fourier coefficients of the two results, an idea of the accuracy of both the curve reproduction method and feasibility of using the trapazoidal rule of integration in such analysis is to be obtained. Also, an estimate of the number of intervals necessary to be plotted with respect to the number of overtones used in order to obtain a certain degree of numerical efficiency is sought.

1864T Agronomy. Soil Management for Claypan Soils. This is a study of procedures used on certain claypan soils. When these procedures are used together, they could form an important part of a soil management program for these soils. The effects of fertility practices, earthworm innoculations, special drainage provisions, and cropping practices are to be compared.

It will be necessary to statistically analyze these data by analysis of variance to complete this study.

1865T Veterinary Physiology. Blood Coagulation. The effect of Methionine, Vitamin K, Estrogen and Testosterone on blood coagulation will be studied. The mathematical method used is least squares.

1866 Digital Computer Laboratory. Magnetic Tape Codes. The problem is to find magnetic tape recording codes having the error-detection, error-correction, and clocking properties described in DCL File 335, while using the minimum number of tape channels. Several cases are to be considered, corresponding to different assignments of the number of tape characters per 52-bit computer word.

Illiac is to be used to test codes thought to have the desired properties. The program to be used checks all characters (of a specified bit length), generating check bits according to a specified encoding matrix, checking the result against the clocking requirement, and printing out indications of failure.

1867 Illinois Geological Survey. Fabric Studies of Sandstones. Sandstones are chiefly composed of elipsoid shaped, closely packed quartz grains. These grains exhibit a statistical preferred orientation inherited from the depositing current. Fabric studies of grain orientation show that adjacent grains tend to have similar orientations, i. e., they are autocorrelated. This "clustering" can be investigated with standard serial correlation methods but possibly more effectively with a non-parametric approach such as the mean difference.

Thus, if $X_1, X_2, \ldots, X_n$ are observed orientations, it is desired to

(1) Form all pairs $|X_i - X_j| = d_{ij}$

(2) Take min $(d_{ij}, 180 - d_{ij}) = c_{ij}$

(3) Compute $\bar{d}_{ij}$, var d_{ij}, $\bar{c}_{ij}$ and var c_{ij}

(4) And print

where $\bar{d}_{ij} = \frac{1}{n} \sum_{ij} d_{ij}$ and var $d_{ij} = \frac{1}{n} \sum_{ij} (d_{ij} - d_{ij})^2$

1868 Chemistry. Theory of Unimolecular Reactions. Hamilton's equations for nuclear motion of the O_3 molecule are to be integrated in order to determine theoretically the lifetimes of the molecule when excited by photon absorption. The results are to be compared with the theories of Kassel and of Slater.

The process involves the random selection of a point in the phase space of the microcanonical ensemble of molecules with a given excitation energy, then integration of the classical equations of motion until the relative positions of the three atoms indicate that one or more of the bonds

have been broken. At various intervals during the integration, the total energy of the molecule will be determined as an accuracy check, and also the energy associated with each bond and normal coordinate will be determined in order to test the validity of assumptions in the aforementioned theories.

1869 Music. Music Transcription. This is a study of the processing of musical and musicological information by means of computers. Its first part will be the converting of various types of coded input derived from a number of musical sources to a standard machine representation which can be utilized for sorting, for analysis, and for musical typewriter printout. In connection with this last item, means are currently being investigated for acquiring or constructing a musical typewriter activated by punched tape. This is intended to be the first of several projects to be supported by the Graduate College and the School of Music to study the applications of computers to musical problems.

1870 State Water Survey. Test of Normality. It is generally desirable to perform some preliminary investigation of any set of numbers which are going to be subjected to statistical analyses such as regression and correlations, for example. The preliminary investigation usually includes a look at the mean, the standard deviation, the variance, and some measure of asymmetry or departure from the normal curve of error. A program of this nature will be useful in the beginning phase of analysis or data reduction of most any variable.

Standard statistical formulas will be used:

(1) Mean $= \Sigma X/N = \bar{x}$.

(2) Variance $= \left[\Sigma x^2 - (\Sigma x)^2/N\right] \Big/ N - 1 = s^2$.

(3) $\Sigma (x-\bar{x})^3 = N \left(\left\{\left[2(\Sigma x)^2 (\Sigma x)\right]/N^2\right\} - \left\{3(\Sigma x)(\Sigma x^2)/N\right\} + \Sigma x^3\right) \Big/ (N-2)(N-1) = Sx^3$.

(4) $Sx^3/s^3 = g$ which is a measure of asymmetry.

(5) $t = g/$(standard error of g) is finally computed for comparison with published t values.

Logarithmic and square root routines will be added to the program eventually. Perhaps other transformations will become desirable also.

Table I shows the distribution of Illiac machine time for the month of January.

TABLE I

	Hrs:Min	
Scheduled Maintenance	64:34	
Unscheduled Maintenance	53:33	
Drum Engineering	5:10	
RAR	:55	
Leapfrog	12:52	
Wasted	:05	
Library Development	1:42	
Classes	:03	
Demonstrations	3:41	
		142:35

Use by Departments

Agricultural Economics	7:12
Agronomy (0015-15-306)	:51
Agronomy	11:52
Animal Science (HATCH 21-15-20-352)	:05
Animal Science	:16
Bureau of Community Planning (84 16 383)	:21
Bureau of Educational Research	5:17
Chemistry (NSFG 7336)	9:58
Chemistry	35:22
Civil Engineering (AASHO ROAD TEST)	2:39
Civil Engineering (NSF-G6572)	7:07
Civil Engineering	45:48
Coordinated Science Lab. (DA-36-039-SC56695)	33:01
Dairy Science	:13
Digital Computer Lab. (NSF GRANT 9503)	31:37
Digital Computer Lab. (AEC AT(11-1)-415)	8:29
Digital Computer Lab. (NONR 1834(27))	1:13
Digital Computer Laboratory	5:32
Economics (NSFG 7056)	1:04
Education	:08
Electrical Engineering (NSFG 7421)	3:30
Electrical Engineering (AF 19(604)-5565)	:13
Electrical Engineering	10:39
Geological Survey	:19
Institute of Communications Res. (44-28-20-378)	:16
Institute of Communications Res. (46-28-20-364)	1:53
Institute of Labor and Industrial Relations	1:13
Inst. for Res. on Excep. Chil. (HE and WSAE 8204)	1:24
Inst. for Res. on Excep. Chil. (USPH NIH M-3207)	2:10

(continued)

Mathematics	10:38		
Mechanical Engineering (DA-11-022-ORD1980)	:10		
Mechanical Engineering	6:00		
Medicine	1:36		
Mining and Metallurgical Engineering (TRUS AF6770)	:07		
Mining and Metallurgical Engineering (CML 51F)	1:56		
Music	1:38		
Physical Education	:32		
Physics (ORD 1001)	:24		
Physics (NONR 1834(05)A)	8:54		
Physics	5:37		
Psychology (MD 2060)	1:25		
Psychology (AF 49(638)371)	7:07		
Psychology (1715)	:03		
Psychology (ONR 46-32-66-362)	:36		
Psychology	69:28		
Sociology	3:43		
State Water Survey (DA-36-039-SC75055)	:14		
State Water Survey	7:51		
Theoretical and Applied Mechanics (NONR 1834(12))	:09		
Theoretical and Applied Mechanics (DA-11-070-508 ORD)	1:49		
Theoretical and Applied Mechanics (AF(616)6643)	1:09		
Theoretical and Applied Mechanics	5:39		
Veterinary Medicine (E 3077)	:08		
Veterinary Physiology	:21		
Williams College	1:06		
		367:38	
			510:13

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of

time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE III

Arithmetic		3
Memory		24
Drum		2
Reader		3
Punch		1
Power Supplies		1
Control		3
Unknown		8
	Total	45

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/3/61	20:33	:01	3:26	1	(1) Brake on reader tore tape.	:00	:09	0
1/4/61	20:26	:30	3:04	1	(1) Unknown	:00	:19	0
1/5/61	13:12	7:18	3:30	4	(1) Voltages in adder off. (2) Memory failures. (3) Unknown. (4) Memory failures.	:00	:41	0
1/6/61	19:56	1:24	2:40	3	(1) Memory failures. (2) Memory failures. (3) Memory failures.	:00	1:04	0
1/9/61	21:19	:11	2:30	2	(1) Unknown. (2) Reader "G" erred.	:00	:24	0
1/10/61	17:55	3:35	2:30	2	(1) Memory failures 2^{-5} and 2^{-3}. (2) Memory failures 2^{-3}.	:00	1:20	0
1/11/61	17:21	4:09	2:30	2	(1) Memory in general failing. (2) Memory, dispatch counter tubes bad.	:00	:27	0
1/12/61	16:22	4:16	3:22	3	(1) Several memory positions giving trouble. (2) Address generator tubes bad. (3) Memory position 2^{-1}.	:00	:40	0
1/13/61	21:29	1:00	2:30	1	(1) Punch 5 failing.	:00	:32	0
1/16/61	20:29	:24	3:07	2	(1) Unknown. (2) Memory $2^{-22} + 2^{-19}$ failing.	:00	:00	0
1/17/61	17:29	2:59	3:32	4	(1) Memory failing. (2) Memory, regeneration tubes bad. (3) Memory, position 2-1. (4) Leapfrog failed-reason unknown.	:00	:23	1
1/18/61	14:05	6:21	3:34	4	(1) Memory still failing. (2) Memory failures. (3) Drum failure. (4) Unknown.	:00	:46	1
1/19/61	13:35	6:55	3:26	1	(1) Switch replaced in control panel.	:00	:28	0
1/20/61	20:22	:52	2:46	2	(1) Bad contact on orange switch. (2) 300 v. power supply.	:00	:42	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/23/61	21:16	:05	2:39	1	(1) Reader "J" making errors.	:00	:00	0
1/24/61	18:08	2:37	3:15	3	(1) Orange switch giving trouble. (2) Division hang-up circuit seemed to be malfunctioning. (3) Unknown.	:00	:27	0
1/25/61	20:51	:26	2:45	3	(1) Leapfrog failing; several memory positions failing. (2) Memory position 2^{-20}. (3) Drum failure.	:00	:23	1
1/26/61	20:51	:26	2:43	1	(1) Memory failure 2^{-20}.	:00	:23	1
1/27/61	21:35	:00	2:20	0		:05	:00	0
1/30/61	20:41	:30	2:49	1	(1) Unknown	:00	:20	0
1/31/61	15:35	5:55	2:30	4	(1) Bad tubes in decoding chassis. (2) Memory failure 2^{-3}. (3) Memory failure 2^{-13}. (4) Memory failure 2^{-13}.	:00	:29	0
TOTALS	387:23	55:04	61:28	45		:05	61:28	4

PART VI

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New 650 Codes

During the month of January, one new routine was added to the Digital Computer Laboratory 650 Library.

Revised K4' - 63' — Analysis of Variance by Method of Fitting of Constants. This is a revision of Library Routine K4' - 63' previously described. The revision corrects and improves the printing portion of the program.

International Business Machines 650 Usage

During the month of January, specifications were presented for nine new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 202'T. Numbers followed by T are for theses.

202'T College of Education. Reliability Study of Judges' Ratings. This is part of a much larger study of the relationship between success in group counseling and discrepancy in levels of personality. The rating scales were either especially constructed or adapted from other studies of success in group counseling. The Need Behavior Scale was constructed to rate the personality traits which are commonly related to a subject's thematic appreciation test stories. The items are based on Methods in Personality Assessment, by Stern, Stein and Bloon.

The Behavior Rating Scale was adapted from the work of Ohlsen and Broedel and is a measure of client behavior and attitudes which are related to mental health. The items were derived mainly from the work of Jahoda on mental health and Maslow's on "self-actualizing" people.

203' Electrical Engineering. Magnetoresistance - 3. This routine will compute magnetoresistance and Hall coefficient as a function of magnetic field for a 3-band model.

$$\frac{\Delta\rho}{\rho} = 1 - \frac{\left[K(\gamma_1) + K(\gamma_2) + K(\gamma_3)\right]^2 + \frac{9\sigma^2 H^2}{64}\left[L(\gamma_1) + L(\gamma_2) + L(\gamma_3)\right]^2}{(\sigma_1 + \sigma_2 + \sigma_3)\,(K(\gamma_1) + K(\gamma_2) + K(\gamma_3))}$$

where: $$K(\gamma_1) = \sigma_1 \left\{1 - \gamma_1 - 2\pi\, \gamma_1^{3/2}\, e^{\gamma_1}\, Ei(-\gamma_1)\right\}$$

$$L(\gamma_1) = \sigma_1\, \mu_1 \left\{1 - \gamma_1^2 - \sqrt{2\pi}\, \gamma_1^{3/2}\, e^{\gamma_1}\left[1 - \mathrm{erf}\sqrt{\gamma_1}\right]\right\}$$

σ = conductivity

μ = mobility

H = magnetic field

This will be used to evaluate data obtained from measurements of grain boundaries in germaniun between 2°K and 77°K.

204' Agronomy. Drainage of a Saturated Column. The problem is that of determining the moisture content of a column of soil which was initially saturated. This requires the solution of a boundary value problem involving a non-linear partial differential equation of parabolic type in two independent variables. The problem is converted to a finite difference problem which requires the solution of a system of linear equations whose matrix is of tri-diagonal form. The moisture content is a certain known constant times the logarithm of the solutions of the above system of equations.

205' Small Homes Council--Building Research Council. One and One-Half Story Truss. The problem consists of determining the unknown moments and joint rotations in a one and one-half story truss.

The solution is to be made by first inverting the 12 x 12 stiffness matrix and then back substituting an arbitrary number of column vectors to obtain solutions for a given configuration.

Several configurations, unknown at this time, will be examined for various conditions of loading.

206' Bureau of Business Management. Northern Illinois Shopping Survey. A consumer shopping habit survey has been taken in six Illinois towns. The shopping patterns and attitudes toward the shopping facilities in several alternative cities are to be studied.

207' Business Office. Accounts Receivable Aging. The 650 computer will be used for aging a student account file on magnetic tape and preparing an aged report for all accounts, for which there is a balance.

In addition, control totals for each aged trial balance will be prepared.

208' Physics. Many-Center Integrals. The calculation of electronic energy levels and wave functions in solids requires evaluation of integrals involving atomic wave functions whose centers of symmetry are at different sites. The machine will be used to calculate the radial coefficients of a function centered on one nucleus in a spherical harmonic expansion about another, and to evaluate the integrals involving these results. In both cases, a simple modification of Simpson's rule is the chief mathematical component of the programs.

The first anticipated application is to the calculation of ground state wave functions for the F-center imperfection in alkali-halides.

209' Physics. Tabulation of Spherical Bessel Functions. The purpose of this program is to obtain spherical Bessel functions and/or Neuman functions in floating point based on the recurrence relation:

$$\left(\frac{2n+1}{z}\right) f_n(z) = f_{n-1}(z) + f_{n+1}(z),$$

starting with the computation of

$$j_0 = \sin x$$

$$j_1 = \frac{\sin x}{x} - \cos x$$

$$n_0 = \cos x$$

$$n_1 = -\sin x - \frac{1}{x} \cos x.$$

210' Physics. Neutron Resonances - Unresolved. Neutron resonance reactions are of great interest in reactor physics. For many applications, it is sufficient to calculate the resonance integrals [1) 2)]. Tables for the characteristic functions J, L are available [2)]. These tables, and associated interpolation procedures do not, however, provide a practicable approach for evaluating effects of the unresolved resonances, where a statistical average is to be made over level spacings and line strengths. For this purpose, the integrals

$$(Av)_{UNRES} = \frac{\sigma_p \Gamma_\gamma}{D} \int_{E_i}^{\infty} \frac{dE}{E} \bar{J}, \quad J(\xi,\beta) = \int_0^{\infty} \frac{\psi(\xi,x)}{\psi(\xi,x)+\beta}\, dx, \quad \bar{J} = \frac{1}{\sqrt{2\pi}} \int_0^{\infty} \frac{dy}{\sqrt{y}}^{-y/2} J(\xi,\beta)$$

have to be evaluated for a wide range of parameters, and use of available tables for interpolation requires a large expenditure of computer time.

To simplify this procedure, it is proposed to obtain a numerical approximation for the function $J(\xi,\beta)$ in the form

$$J^*(\xi,\beta) = \frac{\pi/2}{\sqrt{\beta(\beta+1)}} \quad \frac{1 + \sum_{k=1}^{n} a_k (\xi/\beta)^k + a_{n+1}(\xi/\beta)^{n+1}}{1 + \sum_{k=1}^{n} b_k (\xi/\beta)^k + a_{n+1}(\xi/\beta)^{n+1}}$$

This form for J* leads to expansions for large and small values of the arguments which are identical to the appropriate expansions for J.

In this problem, the International Business Machines 650 will be used first to evaluate the constants a_i and b_i for a variety of approximation polynomials. Afterward, the approximate functions J* will be evaluated for selected values of the argument, and, from a comparison with the already known and tabulated values of J, it will be possible to make a choice of the simplest approximation which will be sufficiently accurate for use in the calculation of resonance integrals.

In determining the approximation polynomials selected values of the arguments of J will be used, and a_i and b_i will be determined by solving a system of 2n+1 linear equations.

To increase the accuracy of the approximation, second or further fits will be made by keeping the a_i or b_i constant and determining the other

set by a least square fit to known values of J.

(1) Weinberg and Wigner, The Physical Theory of Neutron Chain Reactors.

(2) Adler, Hinman, and Nordheim, The Quantitative Evaluation of Resonance Integrals, UN/P/1988, Second Geneva Conference.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of January.

TABLE I'

		Hrs:Min	
Regular Maintenance		19:03	
Unscheduled Maintenance		4:02	
Library Development - DCL		1:14	
Library Development - Agronomy		5:46	
Classes		44:35	
CE 391	7:26		
Math 295	35:14		
Math 395	1:55		
Demonstration		1:30	
Wasted		2:30	78:40

Use by Departments

		Hrs:Min		
Agricultural Economics		4:09		
Agronomy		18:58		
Animal Science		:14		
Astronomy		3:10		
Chemistry		5:02		
Civil Engineering		25:45		
Digital Computer Laboratory		1:49		
Electrical Engineering		7:04		
Graduate College		4:17		
Horticulture		:06		
Mechanical Engineering		4:45		
Physics		4:33		
State Water Survey		5:23		
Statistical Service Unit		142:33		
Admissions and Records	38:14			
Agricultural Extension	3:11			
Bureau of Educational Research	4:39			
Bureau of Institutional Research	1:57			
Bursar's Office	24:39			
Business Office	13:24			
DHIA	35:15			
Education	11:26			
Forestry	:06			
Horticulture	7:01			
Political Science	1:03			
Statistical Service Unit	1:38			
			227:48	
				306:28

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 5:00 p.m. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for January.

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
1/3/61	7:24	3:50	1:42	:04	2	(1) False distributor light. (2) Fuse blew in 653 due to excessive filament wastage.
1/4/61	13:33			:05	1	(1) 407 not spacing properly--had a loose carriage mechanism. Adjusted.
1/5/61	15:33		(:30)* :15	:12	1	(1) 407 sometimes printing leading 0's when it shouldn't.
1/6/61	14:27			:13	0	
1/9/61	9:16	3:47		:02	0	
1/10/61	13:50			:07	1	(1) PR lost a binary bit in pos. 5.
1/11/61	13:19			:15	0	
1/12/61	13:02			:07	0	
1/13/61	13:13			:10	1	(1) Tape unit 2 filled vacuum tube with tape when coming out of high speed rewind--ran okay later.
1/16/61	12:02	3:52		:00	0	
1/17/61	23:58			:04	1	(1) Tape unit 2 dumped tape in vacuum tubes coming out of high speed rewind.
1/18/61	13:42		1:02	:04	2	(1) Random alpha prints on 407. (2) Tape unit 2 didn't come out of high speed rewind correctly.
1/19/61	12:55			:11	0	
1/20/61	12:35			:30	0	
1/23/61	10:51	3:35		:04	0	
1/24/61	13:02			:03	0	
1/25/61	13:04			:05	1	(1) Lost a quinary bit in dist. pos. 1.
1/26/61	13:15			:03	3	(1) Had a false storage selecion light. (2) Multi bits in dist. pos. 7. (3) Tape unit 3 dumped tape in left vacuum column.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
1/27/61	12:54			:06	4	(1) Had a false storage selection light. (2) Multiple bits in dist. pos. 5. (3) Multiple bits in dist. pos. 7. (4) Multiple bits in core loc. 9004.
1/30/61	16:28	3:59	:35		1	(1) Card jam in 533.
1/31/61	12:30		:28	:05	1	(1) Column 76 reads into 9003 incorrectly in pos. 10.
						*In ( ) appears engineering time on some unit but the 650 was continuing to operate. This figure is not included in total engineering time.
TOTALS	280:53	19:03	4:02	2:30	19	

TABLE III'

650 console		6
Distributor		
False light	1	
Lost bit	1	
Multi bits	3	
Program register		
Lost bit	1	
533 read - punch		1
Card jam	1	
653 high-speed storage		4
Fuse blew	1	
Multiple bits in core	1	
False light	2	
407 printer		3
Not spacing properly	1	
Prints incorrectly	2	
Tape, tape unit, or tape control		4
Tape rewinds improperly	4	
Undetermined		1
	Total	19

PART VII

GENERAL LABORATORY INFORMATION

Seminars

"Experience with Compilers and Computer Systems in Large Scale Scientific Computation with Recommendations for the Future", By Professor John Blatt, University of New South Wales, Australia, January 9, 1961.

"Circuit Arrangements for Maniac III Computer", By Walter Orvedahl, Associate Director, Institute for Computer Research, University of Chicago, Chicago, Illinois, January 16, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	10	1	10.75
Visiting Faculty	3	0	3.00
Research Associates	2	0	2.00
Graduate Research Assistants	8	28	23.25
Graduate Teaching Assistants	0	5	2.50
Administrative and Clerical	6	0	6.00
Other Nonacademic Personnel	37	14	42.07
Totals	66	48	89.57

The Laboratory Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbaum, J. E. Robertson, and J. N. Snyder.

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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - CIRCUIT RESEARCH PROGRAM

PART III - MATHEMATICAL METHODS

PART IV - SWITCHING CIRCUIT THEORY

PART V - DATA REDUCTION METHODS

PART VI - ILLIAC USE AND OPERATION

PART VII - IBM 650 USE AND OPERATION

PART VIII - GENERAL LABORATORY INFORMATION

February, 1961

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Physical Aspects Of Machine Construction

1.1 Air Conditioning

The drawings and specifications for the machine air conditioning are complete and the bids have been requested. All holes have been drilled in the computer room floor for air conditioning ducts.

1.2 Core Memory Main Frame

The decision was made to extend the top of the core main frame to the full height of the computer room. The additional space above the two core memories is to be used for interplay control. There will be enough room for 7,000 transistors with use of our conventional chassis, plus a large free area in the center for future use by a core interplay register. This extension was taken into consideration when the core main frame drawings were prepared and the aluminum for stock was ordered.

1.3 Main Computer Frame

The decision was made to have a partial center wall at the cross of the "T" in the main computer frame for benefit of delayed control.

(C. E. Carter and S. Krabbe)

2. Shop Progress

2.1 Chassis Completed Except for Cast Aluminum Frames:

QRM-----No. 1, 2, 3, 6,
$QRM\text{-}D^2$--No. 1*, 2*, 3, 4, 5**,
A-------No. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11**,
$AS\text{-}D^2$---No. 1, 2, 3, 4, 5**,
S-------No. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10**,
FF_c-----No. 1, Flow gating
A_0-A_4---No. 1, End Conn.
A_{44}-A_{44}-No. 1, End Conn.
S_0-S_4---No. 1, End Conn.
S_{40}-S_{44}-No. 1, End Conn.
MAU TEST I, MAU TEST II } MAU Chassis Test

*Wired as MAU Test Driver[2] Chassis

**Spare Chassis

Chassis Waiting For Diodes and Final Inspection:

QRM-----No. 4, 5, 7, 8, 9, 10
FF_c-----No. 2, 3 Flow-gating
FF_d-----No. 1, 2, 3, 4, Flow-gating

In Construction:

QRM-----No. 11
CYCLE TIMER
FF_c-----No. 4, 5, 6, 7, 8
FF_b-----No. 1, 2, 3, 4
FF_a-----No. 1, 2, 3, 4, 5, 6, 7, 8, 9
SAFF----No. 1, 2, 3, 4, Sense Amplifier Flipflops
X-Y DRIVER No. 1
SENSE AMPLIFIER No. 1.

(T. E. Kerkering and F. Serio)

2.2 Test Equipment

Construction and assembly for the new MAU chassis test unit was completed and power applied.

(R. F. Coady, and M. Melman)

3. Drawings

B965 - R-"F" element.

C-967 - QRM 1F-6F, 1R-4R.

D-1009 - QRM,F - Drawn and checked.

D-1024 - A_5R - Checked and sent to Photo-Lab.

C-1091 - FB4C - Drawn and checked.

Complete drawings for power distribution and the necessary specification for construction were prepared.

(C. E. Carter, S. Krabbe, and H. Lopeman)

4. Delayed (or Arithmetic) Control

During January a set of preliminary logical designs of the various parts of arithmetic control were completed. In February these designs were checked, and/or modified and/or redesigned to produce a consistent design for all of delayed control. This up-dating process included the following activities: checking the logical realization of each instruction to verify that the desired operation was performed; verifying that the subsequencing was correctly handled; dividing each sequencing control drawing into control areas to facilitate

identification; labeling wires interconnecting control areas with a consistent notation; and redrawing several of the control diagrams as well as the EAU (Exponent Arithmetic Unit) decoder logic. As an aid in this checking process, a single composite flow chart for all MAU (Main Arithmetic Unit) and EAU operations was made. Except for instruction decoding, this chart symbolically describes both the operations performed by the control logic and the ordering of these operations.

(H. Aiso, C. E. Carter, M. Faiman, S. P. Krabbe, H. E. Lopeman, J. O. Penhollow, R. R. Shively, and R. E. Swartwout)

As a prelude to the layout of delayed control six large charts were prepared. One chart is devoted to each of the following: gates, selectors, EAU decoder outputs and MAU end connection outputs. Two charts are devoted to control status memory elements. All of the control areas - such as A9 for control area 9 of the floating add sequence - are listed across the top of each chart. Down the side of the appropriate chart all the requests, replies or by-passes for the gates, selectors or control status memory elements are indicated. The true and complement outputs of the control status memory elements, EAU decoder and the MAU end connections are also shown. The number of times these requests, replies, by-passes and outputs are used in each of the 89 control areas was tabulated. This information was then used to determine the total fan-in and fan-out requirements on the logical elements involved - such as the gate or selector logic. A record was also made of the number of transistors in each control area and the fan-in and fan-out of the area AND-NOT. The maximum fan-in was 20, however in 60 per cent of the cases, the fan-in was 8 or less. The maximum fan-out was 18, however in 80 per cent of the cases, the fan-out was 8 or less.

(H. Aiso and J. O. Penhollow)

A second preliminary step in the layout of delayed control has been the assignment of layout priorities to the various control sequences. This is necessary because the amount of control logic which can occupy a position close to the gate, selector, EAU decoder and MAU end connection logic is limited. As the layout is currently envisioned, the gate, selector, EAU decoder and end connection logic will occupy the area roughly defined by the intersection of the stem and the cross of the T. This intersection will be called the control

center. The placement of control sequences or partial sequences (loops) will be along the cross of the T and their relative positions with respect to the control center will be based on a figure of merit calculation which is described below.

Estimates were made of the frequency of use of the various delayed control instructions. These frequency estimates were used to obtain a probability, p, that a given control sequence would be used in a random instruction.

The average time required to execute the sequence, t, was calculated from the logical diagrams assuming that the machine was speeded up by deriving gate and selector driver replies from NOT circuits or level restorers rather than from the DRIVER-DRIVER circuits. With this assumption, the time per step for each of a set of seven classes of operations was determined. The time per sequence was then the sum of the appropriate step times.

Class of Operation	Estimated time per step
1. Carry generator and round-off	350 nanoseconds
2. Set M selectors from the division predictor	290 "
3. Set M selectors by any other means	250 "
4. Set any other selector, MAU or EAU	230 "
5. Set a status memory element	170 "
6. Do only register gates or by-passed selector controls	150 "
7. Null step	130 "

The number of transistors, n, involved in the sequence logic was determined using the charts which were previously described. The three quantities, p, t, and n were then combined to obtain a figure of merit.

$$FM = 1000 \frac{p\,t}{n}$$

The results of the figure of merit calculations are listed below in order of priority.

Sequence or Loop	Symbol	Figure of Merit	No. of Transistors
Multiply Loop	M_L	5.0	86
Divide Loop	D_L	3.3	111
Add Loop	A_L	1.3	330

(Continued)

Continued

Sequence or Loop	Symbol	Figure of Merit	No. of Transistors
Clear Add	B	0.92	168
Store	S	0.73	420
Normalize	R	0.68	208
Rest of Multiply	M_{-L}	0.67	154
Correct OV-Detect O	K	0.60	202
Decode	G	0.48	738 *
Shift Loop	F_L	0.20	230
Load Q	L	0.20	100
Exponent Arith.	E	0.18	58
Rest of Add.	A_{-L}	0.14	234
Rest of Divide	D_{-L}	0.14	631
Shift Preliminaries	P	0.13	90
Diff. Absolute Value	V	0.10	145
Rest of Shift	F_{-L}	0.005	160

* The number of transistors involved in decode includes the control status memory elements.

(J. O. Penhollow and R. E. Swartwout)

5. Advanced Control

A register configuration requiring about 2,500 transistors has been adopted, and the general strategy of operation has been decided upon. References to core memory may be classified as:

1. Operands for delayed control
2. Operands for advanced control
3. Results stored by advanced control
4. Results generated by delayed control
5. Words of orders read, initially for advanced control.

Reference to memory is made in strict sequential order in cases 1, 2, 3. In case 4, the store order is by-passed and the memory location referred to is locked out until the store operation is performed at some later stage. In case 5 a more complex strategy is required. On the one hand, a memory reference for future orders might tie up a core memory needed urgently for some operand, while on the other hand, if one always waits until a word of orders has been

completely processed before initiating the fetch for the next word of orders, advanced control is held up waiting for memory between every word of orders. Since many orders do not refer to core memory, the rule adopted is that when advanced control encounters an order which does not refer to core memory, it fetches the next word of orders in parallel with executing this order. Stores into the next word of orders are frequently illegal, but their legality can be checked by the input routine.

(D. B. Gillies and C. S. Wallace)

6. Circuit Design

6.1 Cable Drivers

Feasibility studies were made for several types of cable drivers using NPN and PNP transistors. All drivers are to be fed from typical switching amplifier collectors, inverting or non-inverting, which require 1.3 ma. maximum base drive. The driver base bleeder uses a zener diode for increased bleeder speed. Conversation with Western Electric established that base current surges of a few nanoseconds duration can reach a magnitude of 1 ampere with no damage to the transistor. Texas Instruments felt that surges of several hundred milliamperes can be tolerated as long as the total device dissipation is not exceeded during the transient.

NPN transistors of the 2N708-2N743 types were considered. Design studies indicate that these units can be used as either emitter-follower or switch type cable drivers over the required voltage range. In the case of the emitter-follower, the emitter current was never permitted to go below 3 ma. A difficulty with the emitter-follower circuit is that it is impossible not to unhook the zener diode in the bleeder and still bump the collector to -5 v and bump the base to some positive voltage. The only alternative to unhooking the zener diode is to eliminate the positive base bump and to place a tolerance of ± 1 per cent on the zener diode. An advantage of the NPN transistors is their higher power dissipation rating (360 mw in free air).

The PNP transistor GF45011 and S-166 was considered for emitter follower operation. The same zener diode limitation as exists for the NPN appears. The circuit is further limited by the present supply voltage available and the dissipation ratings of the transistor. Only the minimum output voltage range is feasible in this configuration. The PNP switch type cable driver appears most feasible for these transistors over all voltage ranges,

and is developed in detail in the following paragraphs.

A comprehensive study has been made of a cable driving circuit shown in Figure 1.

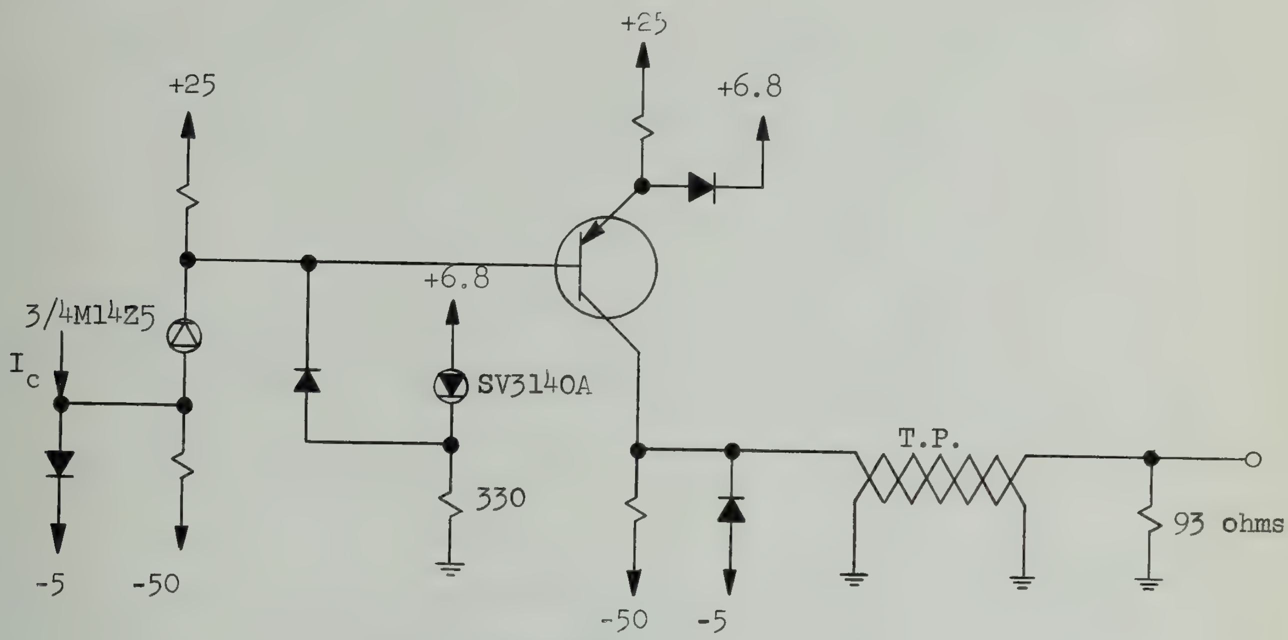


Figure 1

Cable Driving Circuit

The completed report is based on the use of a twisted pair cable whose characteristic impedance is 93 ohms. Since the collector currents at such impedance levels are large, an attempt shall be made to establish a similar cable with a higher characteristic impedance. The report will enable the circuit designer to rapidly select the parameters of a driving circuit over a wide range of output requirements. With the load current and minimum required voltages known, the designer can, with the aid of plotted curves, determine the number of output transistors required and the value of the driver resistors. To operate within the power dissipation limits of the output transistors, the output transistors may be paralleled as required by the output collector currents. Due to the characteristics of the GF45011 and S-166 transistors, an upper limit of $\underline{I}_c = 30$ ma. per transistor was established. In the event that the maximum output voltages exceed the input ranges of the driven circuits, positive and negative stabistor bump circuits may be placed at the sending ends of the cable.

(M. Melman)

6.2 Level Shifts in Non-Restoring Logic

Work was done on computing level shifts for various fan-outs in emitter follower and AND-OR complexes. Corrections were made for base current flow in each case. In the AND-OR complex calculations, the actual value of R_2, 6.5K ohms, was used, rather than the value used in previous calculations. The result appears to be that there is a difference of about 0.05 volts between the original calculations of level shift and the new calculations.

(A. P. Stone)

6.3 Slow Circuits

The design of the slow circuits was completed during the month; see drawing C-1102. Further investigation is being done to determine alternate suppliers of diodes.

(L. J. Peek, and M. D. Freedman)

7. Core Storage Unit

The model memory has now operated for about 2700 hours. Since the 500-hour mark, which is taken as the time to eliminate components high initial failure rate, there has been one component failure--a 2N706 which developed an emitter-base open circuit. This does not include components which may have drifted outside design limits, but have not been located.

The model has had a mean time to error of about 60 hours during February. Several possible reasons for this higher error rate exist and are being investigated.

(S. Ray)

8. Power Supply

The power supply monitoring system has been designed and the required components are on order.

(S. Ray)

9. Magnetic Drum Memory

The specification for the construction of the two magnetic drums in the magnetic drum memory has been completely rewritten. Some of the important parameters are as follows:

Capacity: 65,536 words of 52 bits, plus parities, gaps, spare tracks, and clock tracks.

Number of drums per memory: 2, not phase locked.

Speed: 3500 rpm

Rotor diameter: 10"

Rotor length: 13"

Packing density: 280 bits per inch, NRZ.

Data tracks per drum: 224 plus 32 spares.

Format: Each 52 bit word is recorded as four 14 bit characters on 14 tracks.

Character period: 1.95 μsec.

Word period: 7.8 μsec.

Gap between successive 256 word blocks: 147 μsec.

Write current: < 120 ma.

Read voltage: > 50 mv.

Head inductance: < 50 μh per leg.

For further details, see DCL File No. 332 (Revised) as corrected on February 21, 1961. Copies of this specification have been mailed out for bids. The bids are due on March 23, 1961.

(H. C. Brearley)

Some consideration was given to the sequence of control operations which must occur when access to a particular magnetic drum block is requested. A memorandum was written which discussed the timing restrictions on some of the operations, and which offered a possible scheme. Logical design details are yet to be worked out.

Problems connected with the proposed matrix head selection switch were studied. They include switching transients, transistor storage time, and nonuniformity of diode and transistor characteristics and component values. The scheme proposed offers some advantages.

A short note has been prepared stating the problems and offering some solutions. It indicates two possible schemes for write amplifiers (using saturating or nonsaturating NPN transistors) and two schemes for the read amplifier (using transformer or D.C. coupling). A final choice can be made after some experimentation. D.C. design of the selection switch can be done after selection of transistor types. A list of desired characteristics

for the diodes and transistors has been prepared for comparison with available types.

(P. V. S. Rao)

The logical design of the sector counter and the sector coincidence circuit has been completed.

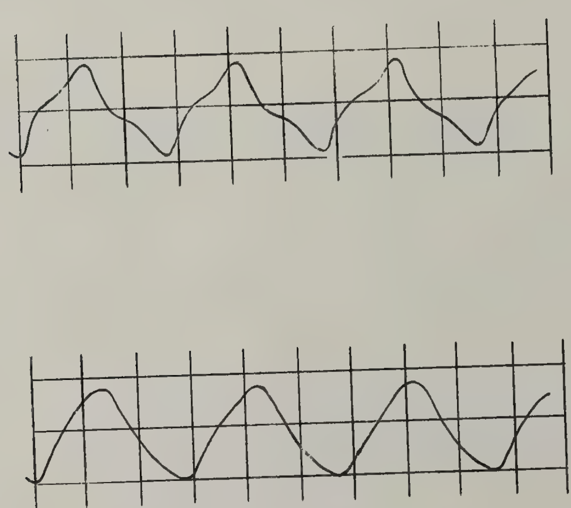
(C. N. Liu)

10. <u>Magnetic Tape Memory</u>

A sample of 3M-8923 thin oxide magnetic tape was tested on the Ampex FR300 tape unit. It was observed that the high frequency response of this tape was considerably better than any other types of tape tested previously. This makes it a superior tape for high density recording. Figure 1 shows the read waveforms from 3M-8923 and Ampex C-1 tape at 466 bpi, 150 ips. The 3M-8923 signal has higher frequency response but only about half the amplitude of the C-1 signal.

The 3M-8923 tape has an extremely thin oxide coating which is easily damaged. The samples which were tested were inadvertently creased during machine threading. For these three possibly damaged samples of 500 feet each, the average permanent-error-free life was approximately 1000 passes. This is essentially the same life as was reported earlier for samples of Ampex C-1 and 3M-159 tape.

(C. N. Liu)



3M-8923 tape
10 μsec./div.
0.5 volt/div.

Ampex C-1 tape
10 μsec./div.
1 volt/div.

Fig 1 - Read waveforms from two kinds of magnetic tape

The search for efficient error-correcting codes for use on the magnetic tape units, mentioned in the December, 1960 Progress Report (Part III, Switching Theory), has led to no better scheme than the base 7 conversion discussed there. Various schemes have been tried, involving complementing all or part of the information bits and check bits, and interchanging the channel assignments of certain bits from the left side of the tape with those from the right, when the given character failed to have at least three one's on each half of the tape. Each such transformation tested failed, but the existence of such a system has not been ruled out.

For the particular case corresponding to code 6 in D.C.L. File No. 335, in which 11 information bits are to be recorded with single error correction, double error detection, and at least three flux changes on each half of the tape, at least 17 channels are required. The base 7 conversion discussed below requires 18, whereas code 6 of File No. 335 required 20.

Conversion to base 7 representation in the excess one's system may be done as follows. An eleven-bit number N may be represented as

$$N = M_1\, 8^3 + M_2\, 8^2 + M_3\, 8 + M_4 \qquad \text{(A)}$$

where

$$0 \le M_i \le 7 \text{ (octal representation)}$$

or

$$N = (N_1-1)\, 7^3 + (N_2-1)\, 7^2 + (N_3-1)\, 7 + (N_4-1) \qquad \text{(B)}$$

where

$$\left.\begin{array}{l} 0 \le N_i-1 \le 6 \\ 1 \le N_i \le 7 \end{array}\right\} \quad \text{(Base 7, excess one).}$$

The numbers N_i are found to be

$$\begin{aligned} N_1 &= M_1 + 1 + C_2 \\ N_2 &= M_2 + 3\, M_1 + 1 - C_2\, 7 + C_3 \\ N_3 &= M_3 + 2\, M_2 + 3\, M_1 + 1 - C_3\, 7 + C_4 \\ N_4 &= M_4 + M_3 + M_2 + M_1 + 1 - C_4\, 7, \end{aligned} \qquad \text{(C)}$$

as can be checked by substitution into (B). Carrying out the substitution indicated,

$$N = \left[(M_1+1 + C_2) - 1\right]7^3 + \left[(M_2 + 3\ M_1+1 - C_2\ 7 + C_3) - 1\right]7^2$$
$$+ \left[(M_3 + 2\ M_2 + 3\ M_1+1 - C_3\ 7 + C_4) - 1\right]7$$
$$+ (M_4 + M_3 + M_2 + M_1+1 - C_4\ 7 - 1)$$
$$= M_1(7^3 + 3\cdot 7^2 + 3\cdot 7 + 1) + M_2(7^2 + 2\cdot 7 + 1)$$
$$+ M_3\ (7 + 1) + M_4$$
$$= M_1(7 + 1)^3 + M_2(7 + 1)^2 + M_3(7 + 1) + M_4$$
$$= M_1\ 8^3 + M_2\ 8^2 + M_3\ 8 + M_4.$$

The role of the C_i is to provide carries so that the N_i remain within their allowed range, $1 \leq N_i \leq 7$. C_i can be represented by three binary digits. For example in Equations (C), for N_4 we have

$$0 \leq M_i \leq 7$$
$$1 \leq M_1 + M_2 + M_3 + M_4+1 \leq 29$$

or, letting $X = M_1 + M_2 + M_3 + M_4+1$, $1 \leq X \leq 29$.

$$\begin{array}{llll}
\text{For} & 1 \leq X \leq 7 & C_4 = 0 & 1 \leq N_4 \leq 7 \\
 & 8 \leq X \leq 14 & = 1 & 1 \leq N_4 \leq 7 \\
 & 15 \leq X \leq 21 & = 2 & 1 \leq N_4 \leq 7 \\
 & 22 \leq X \leq 28 & = 3 & 1 \leq N_4 \leq 7 \\
 & X = 29 & = 4 & N_4 = 1
\end{array} \qquad \text{(D)}$$

Similar relations hold for the remaining C_i. Thus the conversion can be effected with conventional adders and subtractors, plus some special circuits for the generation of the C_i.

Recovery of the original M_i can be effected as follows:

$$\begin{aligned}
M_1 &= (N_1-1) - C_1 + C_2 \\
M_2 &= (N_2 - 3\ N_1+2) - 8\ C_2 + 8\ C_1 + C_3 - C_4 \\
M_3 &= (3\ N_1 - 2\ N_2 + N_3 - 2) - 8\ C_3 + 8\ C_4 + C_5 - C_6 \\
M_4 &= N_4 - N_3 + N_2 - N_1 - 8\ C_5 + 8\ C_6
\end{aligned} \qquad \text{(E)}$$

This can be shown by substituting from (E) into (A) and obtaining (B). In (E) the C_i represent both carries and borrows: C_2, C_3, C_5 are carries from

right to left; C_1, C_4, C_6 are borrows from left to right.

Based on current estimates of the complexity of the "base 7" conversion circuits - in the range of 1000 to 2000 transistors - it is expected that the cost of this system would be comparable to that of the two magnetic tape channels that it replaces.

(R. L. Cummins)

11. Paper Tape Equipment

Bids are being requested for the supply of a 1000 cps reader. Either the Elliot or the Digitronics reader would appear to be quite acceptable.

The logical design of the circuitry for the reader and punch was begun. The circuits will enable reading and punching in either an octal or a 7-level mode, and will recognize and reject non-octal characters in the octal read mode. The circuits will also recognize two sorts of stop characters in either mode, to signal end-of-block and end-of-tape. It is envisaged that after a reader has read an end-of-tape character, it will not respond to further read instructions till a new tape has been inserted.

A fairly simple and apparently satisfactory system of signals for paper tape equipment-computer communication has been designed. It will allow the computer to ignore the timing requirements of the reader and punch without causing errors. It is hoped that the scheme can be adapted for use with other peripheral devices.

(C. S. Wallace and personnel of
Coordinated Science Laboratory)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Introduction

As usual three main areas of research were pursued in February. C. Afuso investigated more in detail the low-swing difference amplifier. In particular relationships between the overswing at the base and switching times were found. H. Guckel continued his work on the high frequency oscillator necessary to drive a mμs shift-time register. Both logical oscillators and more classical layouts were studied. R. Crow examined a more elegant circuit for the measurement of transient base currents.

2. Behavior Of Low-Swing Difference Amplifiers

In order to improve the speed of the low-swing F-element, the basic switching times and waveforms of a difference amplifier were observed. For the difference amplifier shown in Figure 1, the following three quantities are the important factors in determining speeds:

a) The emitter currents, I_e

b) The magnitude of the input pulse, v_b

c) The collector load R.

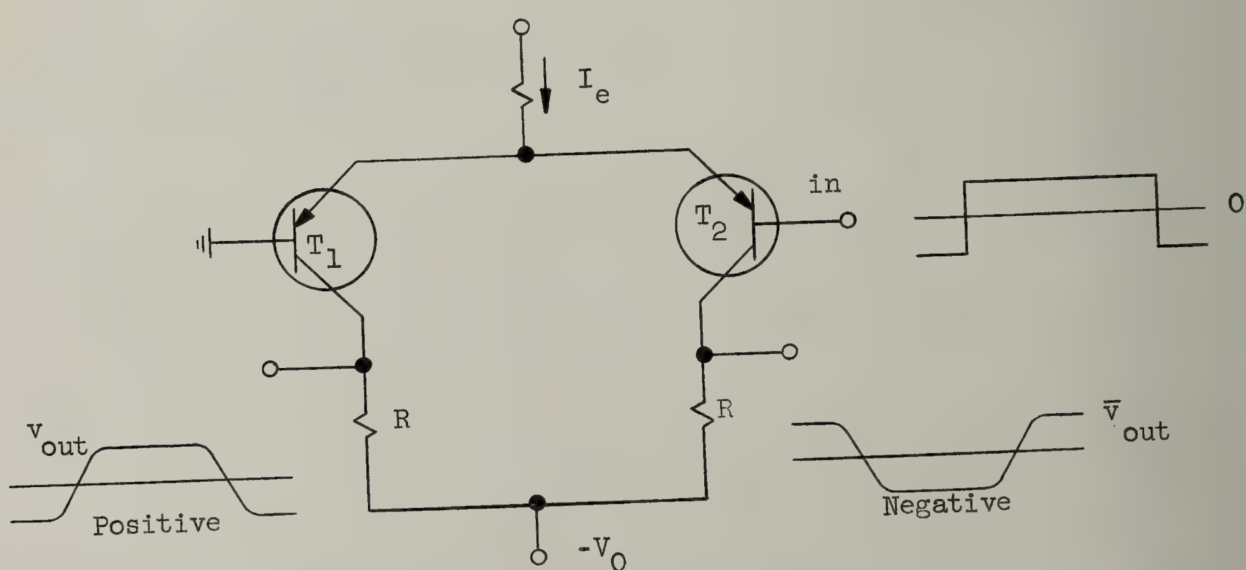


Figure 1

Basic Difference Amplifier

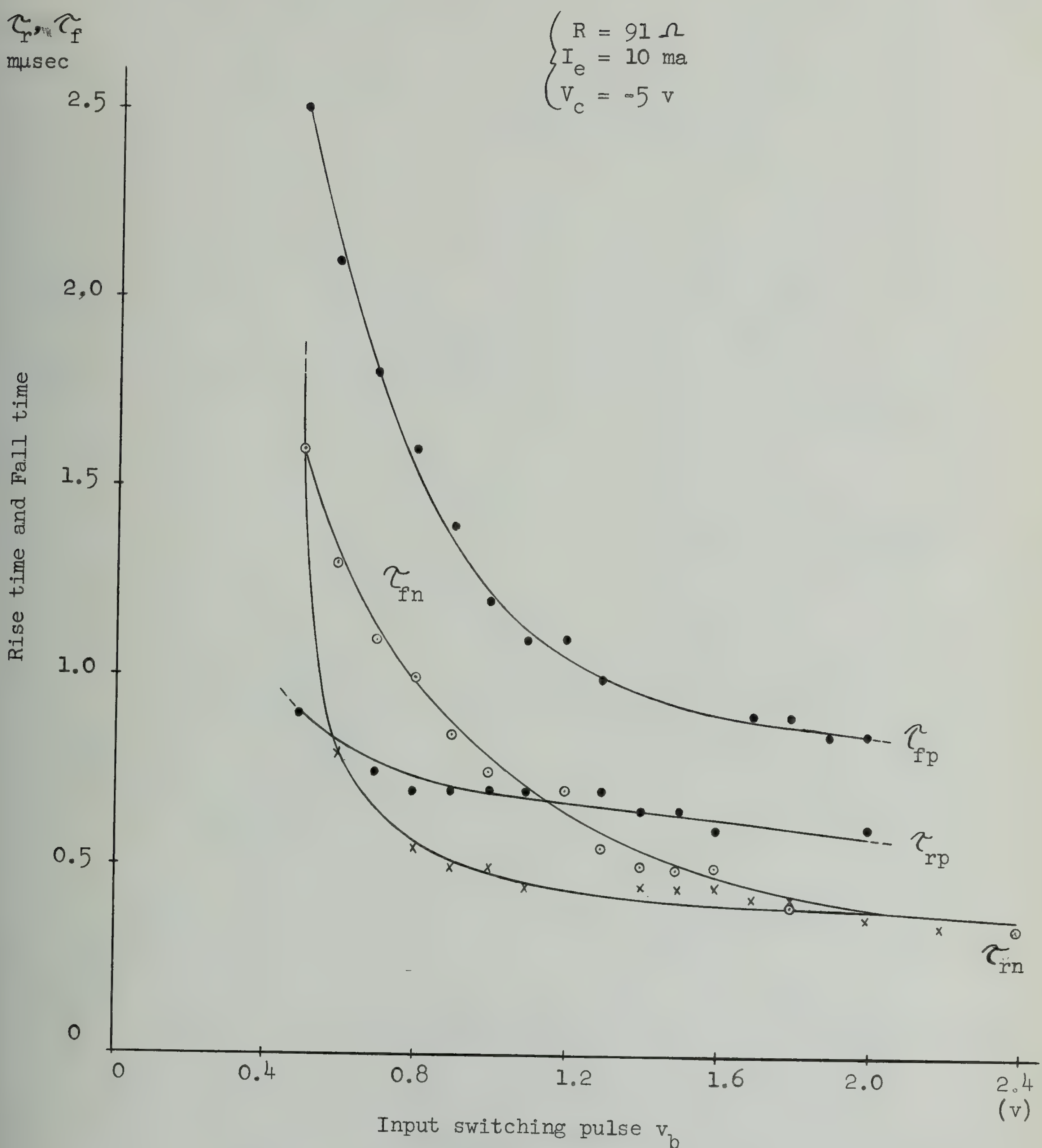


Figure 2
v_b-characteristic of 2 GF45011's In a Difference Amplifier

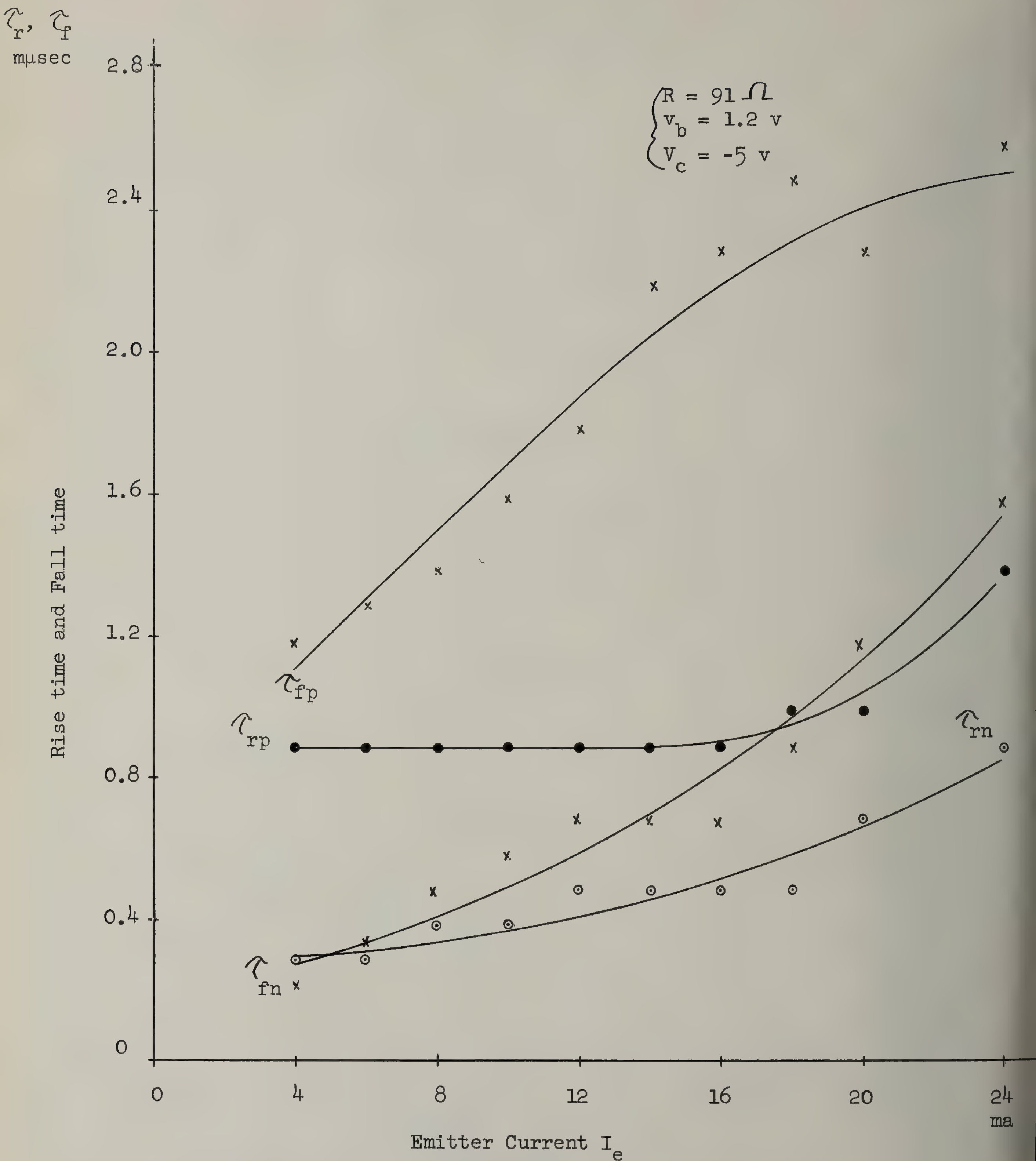


Figure 3

I_e-characteristic Of 2 GF45011's In a Difference Amplifier

Except when the collector voltage V_c leaves an insufficient saturation margin, it does not seem to control the switching characteristics.

The following two kinds of measurement have been made so far:

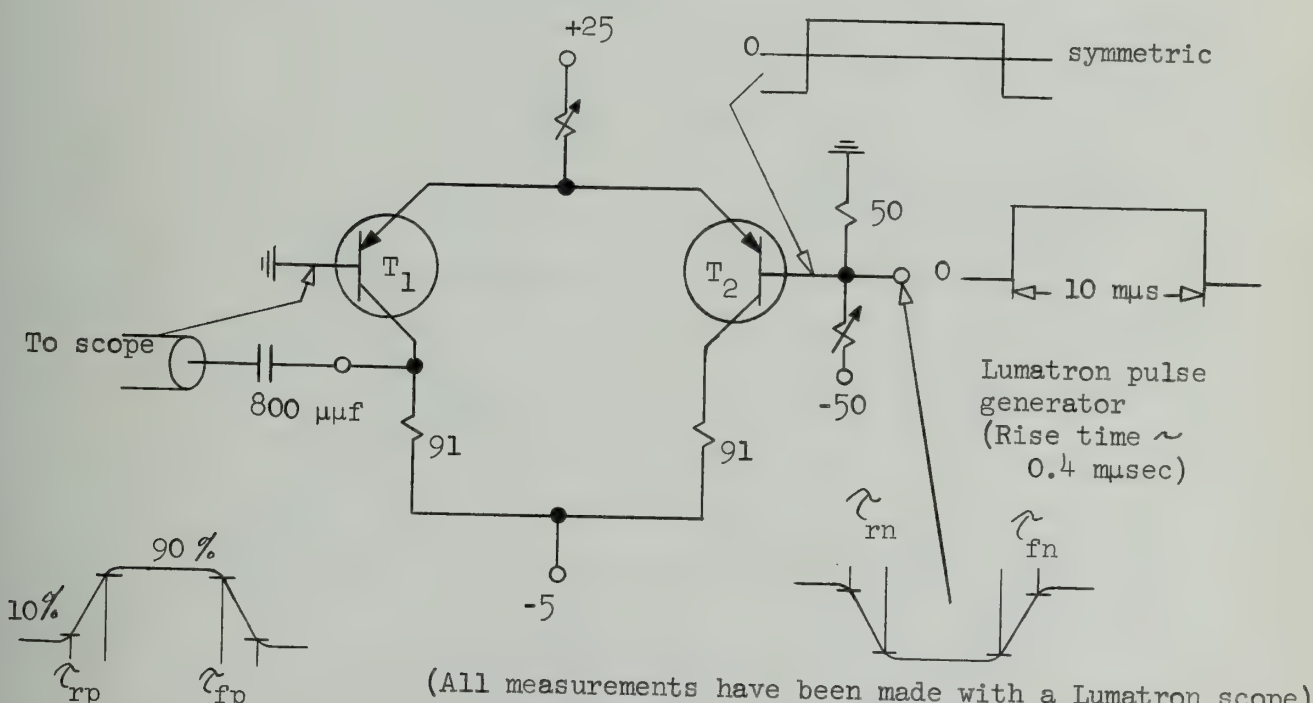
(1) v_b-characteristic

Varying the magnitude of the input switching pulse v_b, the output, v_{out} and $\bar{v}_{out}$, were observed. (I_e and R were kept constant.)

(2) I_e-characteristic

Varying I_e, v_{out} and $\bar{v}_{out}$ were observed. (v_b and R were kept constant.)

For the purposes of the two-wire system (system of difference amplifers), the R-characteristic is also needed. This series of measurements has not been completed yet. The data for (1) and (2) are shown in Figure 2 and Figure 2 and Figure 3. The actual experimental circuit is shown in Figure 4.



(All measurements have been made with a Lumatron scope)

Figure 4

Experimental Circuit To Study Low-Swing Difference Amplifiers

τ_r and τ_f refer to the rise time and the fall time respectively, and the subscripts p and n show the "positive side" v_{out} and the "negative side"

$\bar{v}_{out}$ as indicated above.

The typical waveforms obtained are shown in Figure 5.

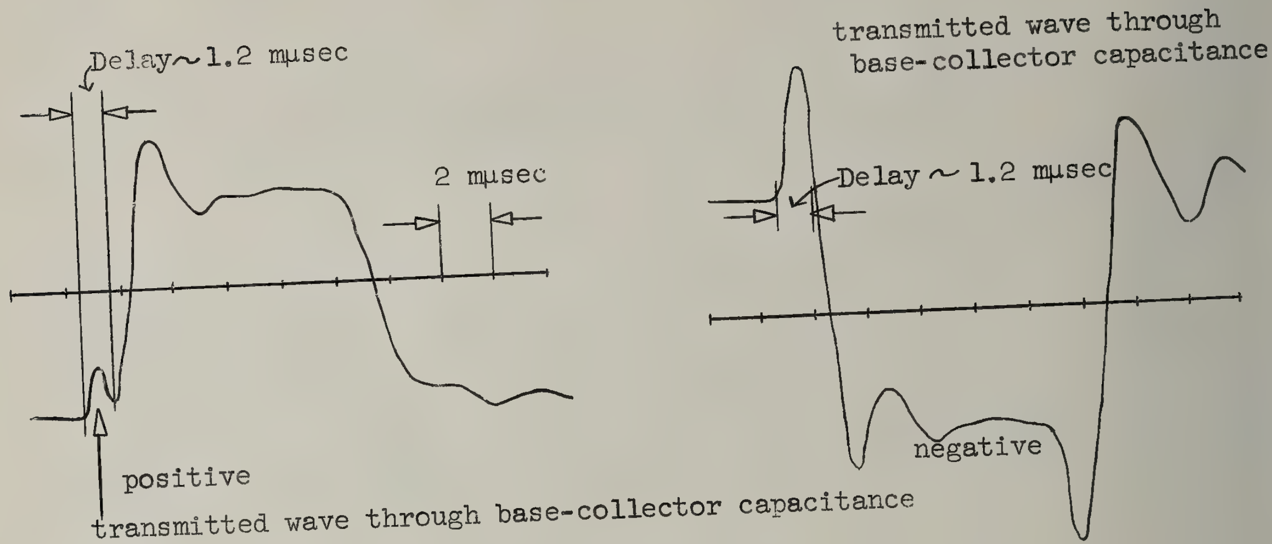


Figure 5

Output Waveforms Of The Low-Swing Difference Amplifier

The above waveforms were observed to remain nearly constant around 1.1~1.2 mμsec. for v_b-and I_e-characteristics.

3. High Frequency Oscillators

a) Square Wave Type:

In order to obtain an idea of the magnitude of driving currents necessary to maintain a reasonable rise time (< 3 nsec), the circuit in Figure 6 was studied:

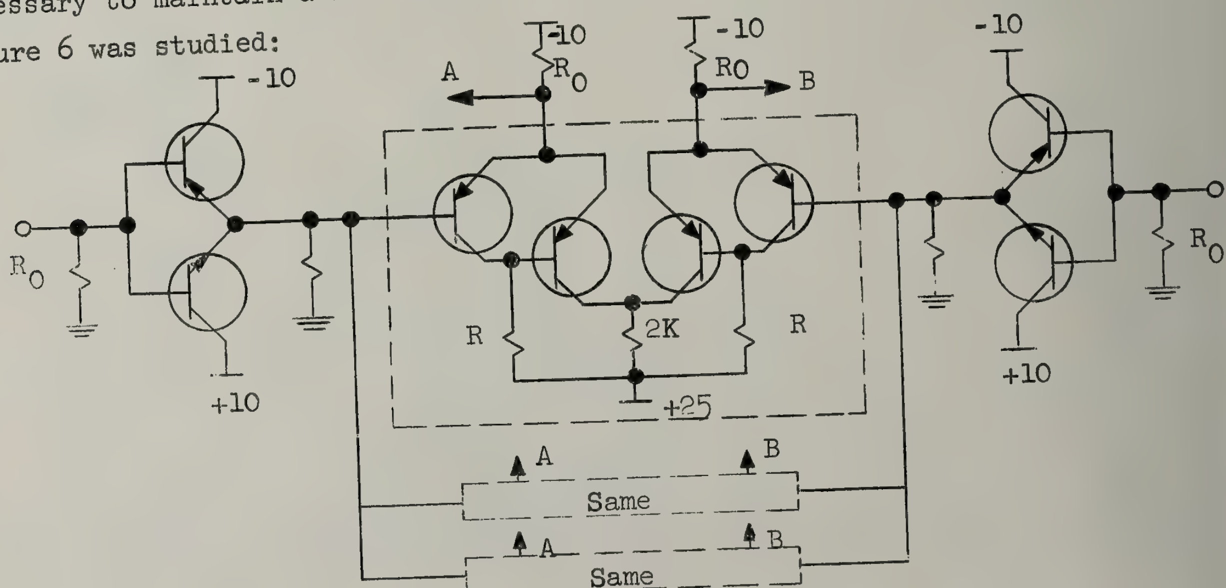


Figure 6
Square Wave Oscillator

The following properties were observed:

1. The rise time in turn-on and turn-off is very fast (1 nsec).
2. The output will not start ringing when voltage overdrive is used, so that the pulse is nearly perfectly flat.

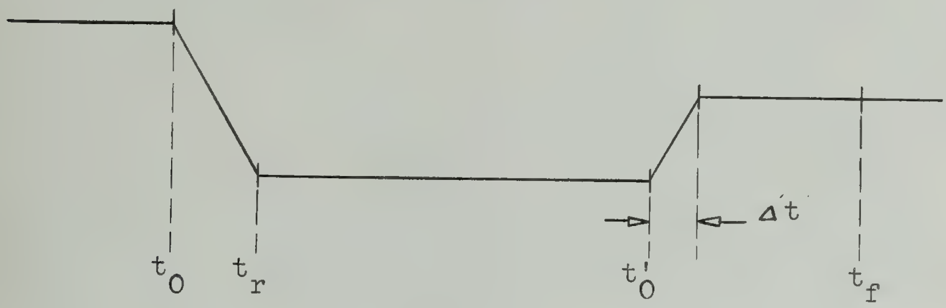


Figure 7
Waveform In The Square Wave Oscillator

The very long turn-off (with respect to the input pulse) was observed for both transistor turn-on and turn-off and was found to be independent of input pulse length. Separation of the two collectors of the paired transistors brought the pulse down in the expected short fall-time. Therefore, it may be concurred that the emitter follower, even though on at all times, is not in a steady state until 12-20 nsec. after the wavefront occurred. This corresponds to previously observed relaxation times due to oscillations.

Since the number of transistors involved in this type of circuitry rapidly becomes prohibitive, it was decided to discontinue the inquiry temporarily.

b) <u>Sinusoidal Oscillators:</u>

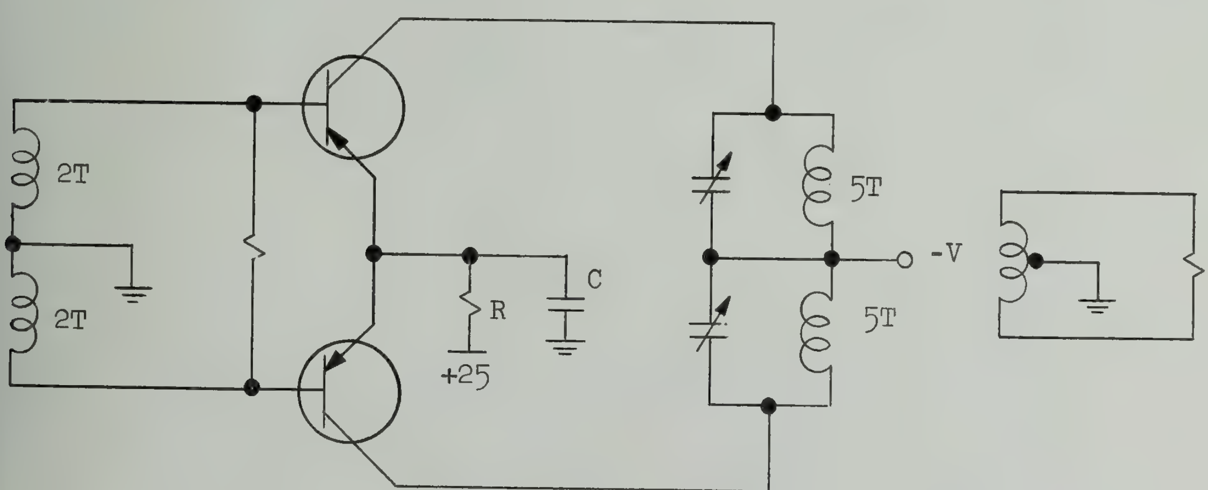


Figure 8
Sinusoidal Oscillator

The circuit in Figure 8 is a modified version of a Hartley oscillator. By adjusting the value of the capacitor C it may be converted from a sinusoidal to a blocking oscillator (single shot). In this form it will produce pulses of about 20 nsec. width with 5 nsec rise time, and a repetition rate of 5-8 mc. As an oscillator it produces the waveform indicated in Figure 9 for V_{cc} = -10V:

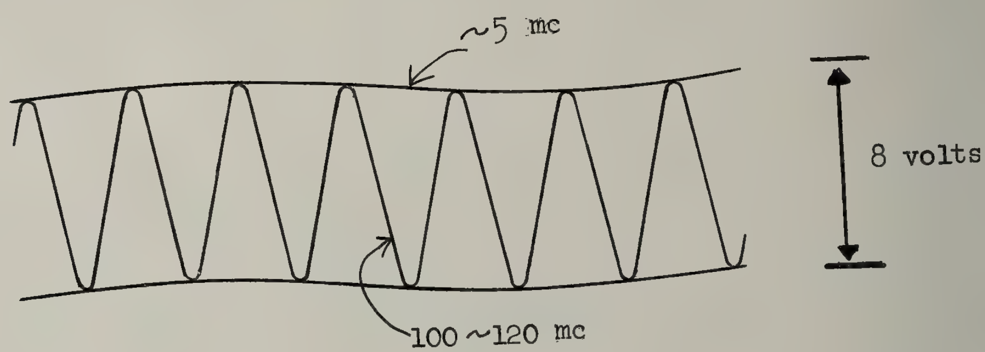


Figure 9

Waveform Of Blocking Oscillator

Nothing has been done to remove the envelope since it is presently being used to obtain a scope synchronization signal. Efforts are being made to utilize this type of circuitry in the proposed test unit.

4. <u>Transient Base Currents</u>

Since the experiments relative to these measurements are still in progress, a complete summary of the subject will be given in next month's report.

PART III

MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research Under Contract Nonr 1834(27).)

Monte Carlo Methods In the Evaluation of Functional Integrals

Work is continuing on the numerical evaluation of functional integrals. A procedure for evaluating averages in quantum statistics using path integrals is being developed. The evaluation of the path integrals will employ techniques described in File No. 361, "Studies in the Numerical Evaluation of Functional Integrals", by L. D. Fosdick.

(L. D. Fosdick)

PART IV

SWITCHING CIRCUIT THEORY

(Supported in part by the Office of Naval Research Under Contract Nonr-1834(27).)

An extensive search has been made for burst correcting codes using the ILLIAC. Codes which correct bursts of length $r + 1$ or shorter are called maximum efficiency codes if they consist of $2^s - 1$ bits of which $s + r$ are check bits. Such codes are generated from polynomials P of the form P_1P_2, where P_1 and P_2 are of degree s and r respectively and where P_1 is primitive. It is necessary that P_2 have a period which divides $2^s - 1$ but P_2 need not be primitive.

Cases were investigated for $s \leqslant 13$. Since the cases for $r = 0$ and $r = 1$ are trivial, the investigation was concerned with $r \geqslant 2$, and tests were made through $r \leqslant 5$. No codes were found except for cases $r = 2$ and $r = 3$ in the in the given range for s. The following results were obtained:

(1) Using $P_2 = t^2 + t + 1$, a total of 150, codes were found for P_1's of various degree.

(2) Using $P_2 = t^3 + t + 1$ five codes were found and using $P_2 = t^3 + 1$, thirty six codes were found. These seem to be the first maximum efficiency quadruple error-correcting codes ever to have been discovered.

Unanswered as yet is the question of the existence of maximum efficiency burst correcting codes of higher r, or for that matter of higher s. Most desirable would be a general method for forming such codes for general s greater than any given value.

(Clinton R. Foulk)

PART V

DATA REDUCTION METHODS

(Supported in part by the National Science Foundation Under Grant G9503)

AUTOMATIC REDUCTION OF DATA FROM BUBBLE CHAMBER PHOTOGRAPHS

An introductory study of the use of factor analytic techniques in pattern recognition has been initiated. To illustrate, a sequence of domains, that is, rectangles, say 10 x 20, but ranging up to 40 x 40 cell divisions are extracted sequentially from a mesh-digitalized photograph. The selection of these domains is dictated by a human scanner. A set of these domains may sample electron spirals of the photographs, or in another experiment be extracted sequentially along beam tracks, etc. For each domain, 16 tests are scored. These tests consist of counting the number of pairs of nearest neighbor cells having a given color sequence, i.e., black black, black white, white black, white white. The local sampling patterns look as below.

These four patterns each permit four boolean possibilities giving 16 tests subject to four constraints defined by the length and width of the domain. Factor analysis enters in the following way. These sequences of domains can be considered a sequence of "subjects". The test scores, i.e., the 16 numbers, can be considered as the examination scores for subjects. The correlations between these scores and the attempt to factor out statistically independent "attributes" can proceed in much the manner as in the statistical methods of psychometrics. Factor analysis as used here is a purely statistical theory without psychological implications. A program to read in specified domains, compute the 16 tests and output this information in a format appropriate for existing multivariant and factor analytic ILLIAC programs has been prepared.

A converse problem, that of artificial picture generation, is also being attacked. In this case, it is assumed that a set of similar appearing domains have been examined by the above named program and that the mean and dispersion of each of the 16 test variables have been computed. The intention here is to use Monte Carlo techniques to generate a statistical ensemble of domains again characterized by the same mean and variance and to visually discern to what extent these artificially generated pictures resemble the

initial set. It is our intention to introduce further n-tuple tests, include test correlations (covariances), and in general introduce one parameter for each principle factor should the above primitive version of artificial regeneration of pictures (i.e., domains) prove successful.

A systematic analysis of digitally tracking approximately 100 tracks is currently under way. Multivariant analysis is again being used to improve the quality of tracking by variation in the tracking parameters and decision algorithm. Approximately 20 tests, such as length of run, density of gaps prior to stopping, tracking oscillation, etc., are prepared for each track segment tracked and examined by this multivariant correlation analysis.

Specifications for a "Digitally Addressed Cathode Ray Tube System," File No. 360, by Bruce H. McCormick, have been prepared.

(K. W. Dickman, K. Hillstrom, M. Kuchnir
B. H. McCormick, F. Shimamoto, J. N. Snyder)

PART VI

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of February, one new routine was added to the Illiac Library.

X 18 - 316 Fake End of Regular Interlude. This program will cause the Illiac to behave as if the order 26 3F7 had been executed. The Williams Memory will be recorded on the drum and SADOI will play in remembering the symbolic address list if 3F7 is in the correct state.

(M. E. Suhre, Jr.)

Illiac Usage

During the month of February, specifications were presented for 17 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 1871T. Numbers followed by T are for theses.

1871T Marketing. Consumption Patterns. The research problem is concerned with consumption patterns in an area which is in the process of economic growth. The method to be used is linear regression, as applied to income and lines of expenditures, within several occupational groups.

1872 Provost. Adjustment for Non-Response Survey of Student Economics. Information on the expenditures, income, assets and debt, along with certain background information from 633 University of Illinois students who kept diaries during the second semester, 1959-1960, has been obtained. Only background information exists for a sub-sample of 206 who failed to respond to the the original inquiry. Using multiple regression, expenditures, income, assets and debt as linear functions of certain relevant variables from the background information will be obtained. Using these functions, expenditures, income, assets, and debt for the 206 non-respondents will be estimated. Then,

by using the actual data from the 633 respondents and the estimated data for the 206 non-respondents with appropriate weights, a sample adjusted for non-response can be obtained.

1873 State Water Survey. Specific Capacity of Deep Wells. There are approximately 115 deep wells in northern Illinois, for which data on specific capacity in gallons per minute per foot have been obtained. The object of the research program is to study the correlations, both simple and multiple, between this variable and various combinations of other variables, such as drift thickness, thickness of formations open to the wells, thickness of dolomite, land and gravel thickness, etc. An attempt will be made to determine and select an empirical equation for specific capacity as a function of one or more of the other variables.

1874 Psychology. Personality Structure in 4-5 Year Old Children. The aims of this research are to verify the results of a previous study in the area of child personality structure and by use of new tests, to obtain further information on established dimensions and isolate new dimensions.

This is essentially a factor analytic problem utilizing the standard routines for correlation, extraction of factors, and rotation of factors. In addition, there will be a short "extension" analysis in order to obtain correlations between tests not used in the factor analysis and the factors obtained from the analysis.

1875 Psychology. Empirical Comparison Between Different Mathematical Methods of Factor Identification. By means of a cross-comparison between several factor analytic studies, all objective test studies in the personality field, the presently available analytic methods for factor identification shall be simultaneously applied and some tests regarding the equivalence of their results will be tried out. This investigation has become necessary since in most studies, only one of these methods has been applied at a time, so that information on specific method comparisons, that is highly necessary, is still lacking.

1876T Civil Engineering. Analysis of Cylindrical Roof Shells. The problem being worked on is the analysis of cylindrical roof shells by use of the energy method and physical models.

In the energy method, the total energy of the shell is first written in terms of the three components of displacement of the shell at the middle surface. Each of these components of displacement are then assumed as the summation of a series of functions. Ritz's procedure is then used to minimize the total energy of the shell to obtain a set of linear equations that determine the undetermined coefficients involved in the assumed series. The solution of these simultaneous equations is to be done by the Illiac.

In the physical model approach, a continuous shell is approximated by a discrete framework consisting of an assembly of rigid bars interconnected by flexible joints and spring elements. The basic idea involved here is to reduce the actual continuous system which has an infinite number of degrees of freedom to one having a finite number of degrees of freedom. The task of finding a solution that satisfies the pertinent equilibrium and compatibility conditions over the complete domain of the shell is then reduced to one of finding a solution that satisfies the same conditions only at a finite number of discrete points. This, essentially, is the physical counterpart of solving differential equations by means of finite-difference approximations. The analysis of this model consists in solving the equations obtained by considering the equilibrium of these bars and joints under loads. The resulting numerical work, therefore, is again one of solving simultaneous linear equations.

The number of equations to be solved in both cases will be varied to study the rate of convergence of both procedures. In later stages, it is desired to write a complete program that is capable of computing all the coefficients needed in the computations.

1877T Agricultural Economics. Programming an Italian Farm. The reorganization of an Italian farm will be planned with standard linear programming techniques. Approximately 15 processes will be considered with 12-15 restrictions.

1878 Finance. Urban Land Values. Multiple correlation with 22 non-eliminated variables will be done to study the significance of various influences on urban land values. Mathematical procedures will follow the K-16 routine.

The variables include several sets of dummy variables used where discrete classifications are present.

1879 Theoretical and Applied Mechanics. Curved Rail Rocket Launcher. The problem concerns the motion of a rocket on a slightly curved launcher rail. It reduces to the solution of two sets of simultaneous differential equations. The first set governs the system when the rocket does not move relative to the launcher, and the second set of equations governs the system when there is relative motion between the rocket and the launcher.

Illiac subroutine F6 will be used to integrate the two sets of simultaneous equations. The other subroutines will be used for input, print-out and computing coefficients in the equations.

1880T Civil Engineering. Analysis of Plates with Stiffened Openings. Basically, the problem is that of solving a fourth order partial differential equation for the deflection of a loaded plate. Finite difference operators corresponding to a differential equation may be derived by direct substitution of appropriate difference equations into the governing differential equation. The boundary conditions are complex, but by using a physical model of the plate and stiffening beams, difference equations can be derived directly. Using the appropriate operator for each given point on the slab, a set of simultaneous equations may be written and subsequently solved for the resulting deflections. From the deflections, the shears, moments, and reactions may be found. The primary use of the Illiac will be to solve the simultaneous equations.

1881 Illinois Geological Survey. Fabric Studies of Sandstones. Sand grains exhibit a statistical, preferred orientation inherited from the depositing currents. Fabric studies of dimensional grain orientation in one plane of the bedding show that adjacent grains tend to have similar orientations; i. e., they are autocorrelated.

Program K-5, serial correlation, will be used to investigate "clustering" in the shape fabrics of sandstones.

1882 Agricultural Economics. Livestock Model I. The model is concerned with estimates of supply and demand of livestock products on a quarterly basis at three levels at the farms, at wholesale, and at retail.

The first sets of equations are all of the linear multiple regression type in natural units.

1883 Mechanical Engineering. Helical Gear Design. Gear specifications satisfying the three basic criteria of strength, wear and scoring within certain prescribed limits will be obtained for given operating conditions.

The Illiac will be used to solve design equations of the form:

$$L = \sqrt{(x + A)^2 + (x \cos \phi)^2}$$

$$z = k_1 D_y^2 \sin \phi \left[\frac{B}{C + D}\right]$$

$$\delta = k_2 \quad y\frac{E}{F}$$

It is expected that the floating decimal routines will be adequate for solving the problem.

1884T Physical Education. Factor Analysis of Electrocardiograph Recordings. The study is concerned with the determination and identification of the various factors associated with electrocardiograph recordings. More precisely, the purpose of this study is to determine the nature of the factors which underlie electrocardiograph test variables by means of the principle axes method of factor analysis and by means of rotation of those principle axes with latent roots greater than one.

1885T Electrical Engineering. Simultaneous Difference Equation. The behavior of a feedback system is described by a system of difference equations of the form:

$$x_{n+1} - x_n = \frac{Ay_n}{1+By_n}$$

$$y_{n+1} - y_n = Cx_n + Dy_n$$

where A, B, C, D are constants determined by the system parameters.

The problem is to find a critical solution curve which separates the x,y plane into stable and unstable regions. To achieve this, assume an arbitrary initial point $x_0 y_0$ and find the value x_N when y_N = K, K being specified beforehand. For different values of x_0, x_N can then be plotted as a function of x_0 and stability can be determined from the characteristics of x_N. It is desired that solutions be calculated for various combinations of system parameters.

1886 Agricultural Engineering. Unit-Flow LP Problem. This problem is an application of linear programming to the problem of selecting the minimum cost materials handling system for a farm. The formulation requires solutions with values equal to only 0 or 1 for a meaningful answer, and solutions are usually of this form. This LP model is unique in that it correctly handles fixed costs in a cost-minimization problem.

Much larger problems of this type will probably arise in the future. Since the original matrix contains only 0 and 1 values, the possibility of a special linear programming code to take advantage of the integer nature of the values should be considered.

1887T Chemistry. Ionization of Polyelectrolytes. Polymers carrying ionic functional groups ("polyelectrolytes") ionize partially when dissolved in a polar solvent. The increase in charge density in the vicinity of the polyion and the repulsion of the charges of like sign on the polymer cause an expansion of the polymer chain. The expansion is lessened somewhat by the presence of the ionized small ions ("counterions") surrounding the polyion, as well as by the field induced by any additional ions present. The effect also depends on the temperature and the nature of the solvent. No analytical theory is presently known that is adequately able to treat this effect for real polymer chains.

It is proposed to use a Monte Carlo method for the numerical solution of this problem. A given polymer, from a set of polymer chains previously generated on the Illiac, is fed into the Illiac, and placed on an appropriate lattice. Ionic sites are chosen on the polymer and counterion sites, in number equal to the number of polyion sites, at random from the remaining available lattice points. The whole system is placed in a box of fixed size.

Such a system constitutes a "configuration". The energy of the configuration is determined. A second configuration is now generated by picking a counterion, at random, and moving it to a new site, also chosen at random. The energy is again calculated and compared with the energy of the previous configuration. The configuration is accepted or rejected according to a fixed procedure.

Let D = the dielectric constant

q = the electronic charge

T = the absolute temperature

k = the Boltzmann constant

r_{ij} = the distance between ion i and ion j

Then:

$$B = \frac{1}{2} q^2/DkT$$

$$E = \sum_{i,j} \pm 1/r_{ij}$$

Where B is an adjustable parameter, and E is the total energy (E' refers to the energy of the new configuration).

If $E' \leq E$, the new configuration is accepted. If $E' > E$, $\exp B(E-E')$ is compared with a random number uniform on the interval (0,1). If $\exp B(E-E') >$ the random number, the new configuration is accepted; otherwise, the new configuration is rejected. The new configuration, if accepted, now takes the place of the old one. If it is rejected, the old configuration is retained. In both cases, a third configuration is generated and compared with the previously retained configuration; the procedure is repeated.

It can be shown on the basis of the theory of Markov chains that the average properties of the system using this procedure converge to the true average properties. It is expected that convergence will take place fairly rapidly for a system of this type. The properties of interest are the average energy and the average position of the counterions. Each configuration recurs with a probability proportional to $\exp(-BE)$ and

$$E_{av} = \frac{\sum_i g_k E_i \exp(-BE_i)}{\sum_i g_k \exp(-BE_i)}$$

as is required. From the average energy, it should be possible to calculate the mean dimensions of the polyion, and thus, in effect, solve the original problem.

Table I shows the distribution of Illiac machine time for the month of February.

TABLE I

	Hrs:Min	
Scheduled Maintenance	65:55	
Unscheduled Maintenance	11:43	
Drum Engineering	4:37	
R. A. R.	:18	
Leapfrog	8:04	
Wasted	:13	
Library Development	6:20	
Demonstrations	1:27	
Classes	1:34	100:11

Use by Departments

Agricultural Economics	8:46
Agricultural Engineering	:06
Agronomy (0015-15-306)	6:27
Agronomy	6:47
Animal Science	:03
Bureau of Community Planning (84 16 383)	:40
Bureau of Educational Research	2:30
Chemistry (NSFG 7336)	9:20
Chemistry	26:20
Civil Engineering (NSF G6572)	7:18
Civil Engineering (AASHO ROAD TEST)	2:48
Civil Engineering	60:12
College of Medicine (NIMH-USPH M-637)	4:11
Coordinated Science Lab. (DA-36-039-SC56695)	43:19
Digital Computer Lab. (AEC AT(11-1)-415)	:43
Digital Computer Lab. (NSF GRANT 9503)	5:21
Digital Computer Lab. (NONR 1834(27))	4:57
Digital Computer Laboratory	3:09
Economics (NSFG 7056)	1:52
Economics	:15
Education	:12
Electrical Engineering (NONR 1834(22))	:52
Electrical Engineering (NASA-NSG24-59)	:13
Electrical Engineering (NSFG 7421)	:03
Electrical Engineering (IOWA GRANT 1955)	:45
Electrical Engineering (AF 7043)	:57
Electrical Engineering	13:27
Finance (IHR-71)	:22
Geological Survey	1:01
Health Service	:23

Illinois Conservation (47-26-82-313)	:33		
Institute of Communications Res. (44-28-20-378)	4:41		
Institute of Communications Res. (USPHM-3941)	4:45		
Institute of Labor and Industrial Relations	:41		
Inst. for Res. on Exceptional Children	:05		
Inst. for Res. on Excep. Children (HE AND WSAE 8204)	6:57		
Mathematics	3:17		
Mechanical Engineering (DA-11-022-ORD 1980)	:46		
Mechanical Engineering	7:02		
Mining and Metallurgical Eng. (TRUS AF 6770)	:18		
Mining and Metallurgical Eng. (CML 51F)	:09		
Music	1:29		
Physical Education	:30		
Physics (NONR 1834(05)A)	5:33		
Physics	6:56		
Provost	1:58		
Psychology (MD 2060)	3:15		
Psychology (AF 49(638)371)	10:00		
Psychology (SAE 8383)	2:52		
Psychology (1715)	9:34		
Psychology (ONR 46-32-66-362)	:13		
Psychology	74:40		
Sociology	:47		
State Water Survey	11:35		
Theoretical and Applied Mechanics (DA-11-070-508)	2:04		
Theoretical and Applied Mechanics (AF(616)6643)	2:12		
Theoretical and Applied Mechanics	4:21		
Veterinary Physiology	:12		
Zoology	1:19		
Williams College	3:29		
		385:29	
			485:40

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance, and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m.

and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for February.

TABLE III

Memory	3
Arithmetic	1
Reader	3
Punch	0
Drum	2
Power Supplies	2
Overrun of Scheduled Engineering	1
Unknown	4
TOTAL	16

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/1/61	19:16	1:46	2:58	4	(1) Over run from scheduled engineering. (2) Memory failure 2^{-8}. (3) Reader error, Reader B. (4) Unknown.	:00	:25	0
2/2/61	21:25	:05	2:30	1	(1) Brake on Reader C out of adjustment.	:00	:37	0
2/3/61	21:16	:46	1:58	2	(1) Memory pos. 2^{-15}. (2) Unknown.	:00	:45	0
2/6/61	21:40	:00	2:20	0		:00	:08	0
2/7/61	21:13	:17	2:30	2	(1) Drum failure. (2) Fuse blew in +300.	:00	:51	0
2/8/61	18:50	2:40	2:30	2	(1) Light in Reader "F" bad. (2) Resistors in RI broken.	:00	:21	0
2/9/61	20:48	:47	2:25	1	(1) Leapfrog failed, cause unknown.	:00	:56	1
2/10/61	18:31	2:51	2:30	2	(1) DC and AC marginal failure. (2) Memory pos. 2^{-2} failing.	:08	:20	0
2/13/61	19:59	:36	3:25	1	(1) Unknown.	:00	:10	0
2/14/61	20:59	:00	3:01	0		:00	:11	0
2/15/61	21:44	:00	2:16	0		:00	:07	0
2/16/61	21:57	:00	2:03	0		:00	:43	0
2/17/61	22:07	:00	1:53	0		:00	:17	0
2/20/61	15:57	:00	8:03*	0		:00	:17	0
2/21/61	21:17	:00	2:43	0		:00	:05	0
2/22/61	22:20	:00	1:40	0		:00	:02	0
2/23/61	22:45	:00	1:15	0		:00	:17	0
2/24/61	22:17	:00	1:43	0		:00	:15	0
2/27/61	12:45	:00	11:15*	0		:00	:13	0
2/28/61	21:39	:14	2:02	1	(1) Work on air conditioner on drum.	:05	:12	0
TOTALS	408:45	10:02	61:00	16	*Time scheduled for general Illiac overhaul.	:13	7:12	1

PART VII

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New 650 Codes

During the month of February, two new routines were added to the Digital Computer Laboratory 650 Library.

Fl' - 69' <u>High Precision Floating Point Runge - Kutta I.</u> This program uses a variant of the Runge-Kutta Method known as Kutta's Simpson's Rule (See "Numerical Solutions of Differential Equations" by H. Levy and E. A. Baggott, Dover Publications, Inc., 1950). A brief description of this algorism is given in the following paragraph.

Consider the set of n simultaneous, first-order, ordinary differential equations:

$$y_i' = f_i(y_0;\ y_1;\ \ldots.;\ y_{n-1}),\ i = 0,\ 1,\ \ldots.,\ n\text{-}1$$

and a set $\{y_{i,\ 0}\}$ of initial values, where a second subscript equal to zero has been used to identify these initial values. Let t represent the independent variable, the initial value being denoted by t_0. The solution at $t = t_0 + h$ is represented symbolically by $\{y_{i,h}\}$. The algorism used here is characterized by the following set of equations for $y_{i,h}$, which applies for i=0, 1, ..., n-1.

$$y_{i,h} = y_{i,0} + \frac{1}{6}\left\{\Delta_1 y_{i,0} + 2\,\Delta_2 y_{i,0} + 2\,\Delta_3 y_{i,0} + \Delta_4 y_{i,0}\right\}$$

where

$$\Delta_1 y_{i,0} = hf_i(y_{0,0};\ y_{1,0};\ \ldots.;\ y_{n-1,0})$$

$$\Delta_2 y_{i,0} = hf_i(y_{0,0} + \frac{1}{2}\Delta_1 y_{0,0};\ y_{1,0} + \frac{1}{2}\Delta_1 y_{1,0};\ \ldots;\ y_{n-1,0} + \frac{1}{2}\Delta_1 y_{n-1,0})$$

$$\Delta_3 y_{i,0} = hf_i\,(y_{0,0} + \tfrac{1}{2}\Delta_2 y_{0,0};\ y_{1,0} + \tfrac{1}{2}\Delta_2 y_{1,0};\ \dots;\ y_{n-1,0} + \tfrac{1}{2}\Delta_2 y_{n-1,0})$$

$$\Delta_4 y_{i,0} = hf_i\,(y_{0,0} + \Delta_3 y_{0,0};\ y_{1,0} + \Delta_3 y_{1,0};\ \dots;\ y_{n-1,0} + \Delta_3 y_{n-1,0})$$

In this notation, the following convention is to be understood: if the independent variable appears explicitly in the differential equations it is here identified with one of the y_i's, say y_0 (i.e., $t = y_0$). This is a fourth-order approximation, the truncation error being of the order h^5. To put it more precisely, this algorism for $y_{i,h}$ agrees identically with a Taylor series expansion about $y_{i,0}$ up to and including terms in h^4, but it disagrees in higher order terms. This statement is not equivalent to saying that a Kutta method is exact for polynomials of up to 4th degree.

In this program, the step-by-step solution of the set of differential equations proceeds as follows.

During the execution of one integration step, the four sets of quantities $\{h^{-1}\Delta_1 y_{i,0}\}$, $\{h^{-1}\Delta_2 y_{i,0}\}$, $\{h^{-1}\Delta_3 y_{i,0}\}$ and $\{h^{-1}\Delta_4 y_{i,0}\}$ are evaluated by an auxiliary routine which must be written by the user. The main program makes entry to the auxiliary four times during an integration step to obtain these four quantities. On the first entry, the main program loads a block of locations called the function block with the values of the variables $y_{0,0}$, $y_{1,0}$, $y_{2,0}$, ..., $y_{n-1,0}$. The auxiliary uses these quantities to evaluate $h^{-1}\Delta_1 y_{0,0}$, $h^{-1}\Delta_1 y_{1,0}$,

$h^{-1}\Delta_1 y_{2,0}, \ldots, h^{-1}\Delta_1 y_{n-1,0}$, and then it transfers control back to the main program. On the second entry, the main program loads the function block with

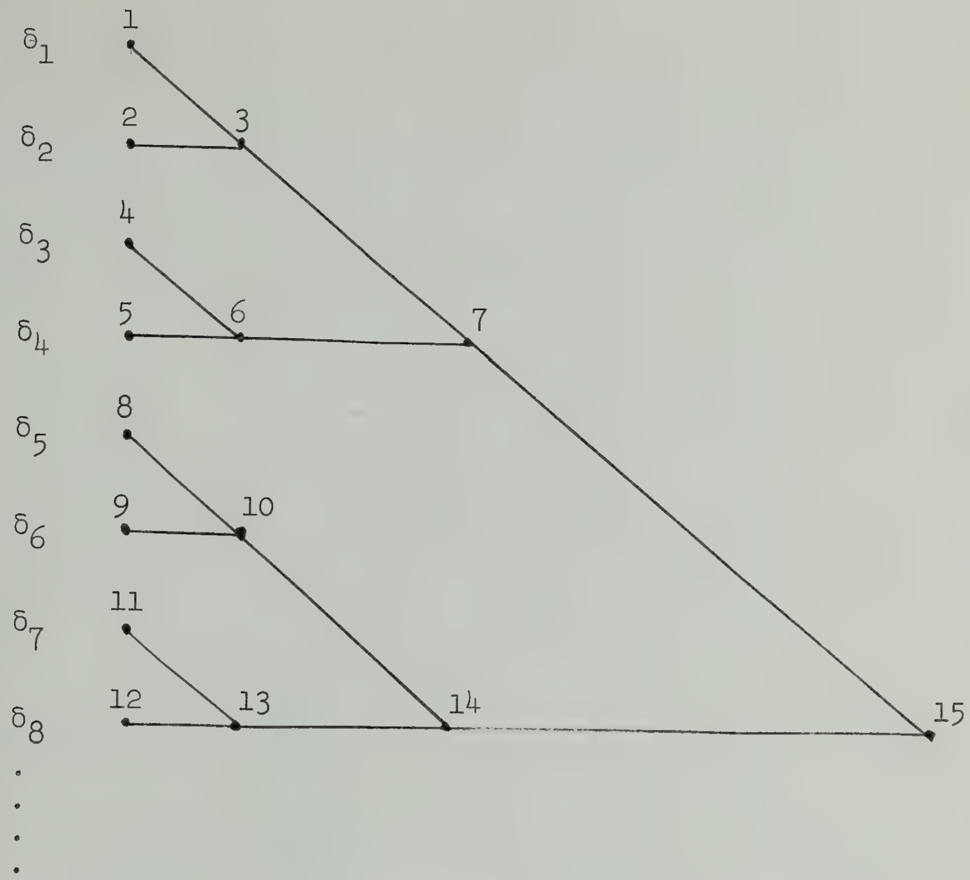
$$y_{0,0} + \frac{1}{2}\Delta_1 y_{0,0},\ y_{1,0} + \frac{1}{2}\Delta_1 y_{1,0},\ \ldots\ldots,\ y_{n-1,0} + \frac{1}{2}\Delta_1$$

$y_{n-1,0}$; the auxiliary evaluates the quantities $h^{-1}\Delta_2 y_{0,0}$, $h^{-1}\Delta_2 y_{1,0}$, $h^{-1}\Delta_2 y_{2,0}$, ..., $h^{-1}\Delta_2 y_{n-1,0}$, and again transfers control back to the main program. The next two entries proceed in a corresponding fashion. At the completion of the fourth entry to the auxiliary the main program evaluates the quantities $\{y_{i,h}\}$ and then the next step begins, with the set $\{y_{i,h}\}$ now replacing the set $\{y_{i,0}\}$. This process continues in this step-by-step manner with intermediate printing of the results as specified by the user by means of a data card. Finally, after a certain number of steps, N, have been completed this process stops; N is also specified by the user with a data card.

All of the arithmetic is performed in floating point. Particular care is taken to keep the round off error small. Let us now consider the technique that is used for this. At the completion of the r^{th} step we may write

$$y_{i,rh} = y_{i,0} + \frac{h}{6}\sum_{j=1}^{4r} \alpha_{i,j}\ (h^{-1}\Delta_{i,j})$$

where the $\Delta_{i,j}$ are the increments to the solution and the $\alpha_{i,j}$ are the multiplying coefficients, 1 or 2, for these increments. For brevity, let us now drop the index i and let $\alpha_{ij}\Delta_{ij}$ be represented simply by δ_j. As the δ_j are computed they are accumulated in a binary ladder like that described for library routine El'. The logic of this accumulation process is illustrated in the picture which follows.



The quantity δ_1 is computed first, the quantity δ_2 is computed second. These are now combined to form $\delta_1+\delta_2$ as indicated by the joining of the lines from δ_1 and δ_2. Next, δ_3 is obtained, then δ_4 is obtained and these are combined to form $\delta_3+\delta_4$ and then this sum is combined with $\delta_1+\delta_2$ to form $\delta_1+\delta_2+\delta_3+\delta_4$. Next, δ_5 is obtained, and so forth. The joining of lines in this picture indicates a summation and the number at the point at which the lines join indicates the order in which the operations are performed. The strategy of this process is to try to add numbers together which are approximately of the same order of magnitude, thus minimizing the loss of significant digits, which is caused by the right shift executed in aligning the decimal point during the execution of a floating point addition. At the beginning of each integration step the partial sums in the binary

ladder are added together and the resultant sum is added to y_0 to form y_{rh} (assuming r steps have been executed). Hence, the current value of the solution is computed anew at the beginning of each step. As soon as δ_j has been computed by the main program, it is added into the ladder. Thus, this step in the summing process takes place after every exit from the auxiliary.

The rather elaborate process used for the accumulation of the sums is programmed as efficiently as is possible with respect to execution time at the expense of storage space. Each function y_i requires a separate binary ladder. The storage for each ladder and the orders for summing the items in that ladder are located in one band on the drum. When a δ_j is to be added into the ladder, or when the partial sums in the ladder are to be combined at the start of an integration step, this band is transferred to the IAS and the summation takes place within the IAS.

(Candace Wilmot)

P9' - 70' <u>Memory Dump on the 407 with Zero Deletion and Control Card Entry. To be used with Digital Computer Laboratory Panel No. 4 (SALT Board).</u> The purpose of this routine is to dump non-zero memory on line on the 407 after program hangup. It also prints the contents of the upper accumulator, lower accumulator, distributor, I.A.A., I.A.B., and I.A.C. at the hangup.

(Ross Flenner)

<u>International Business Machines 650 Usage</u>

During the month of February, specifications were presented for six new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 211'. Numbers followed by T are for theses.

211' Chemistry. WKB Energy Levels. The underlying research problem is the interpretation of the infrared spectrum of VCl_4. Approximate vibrational potential energy surfaces have been determined. The 650 will be used to aid in finding energy levels for these surfaces. As a first approximation, the WKB method is being applied. The problem has been reduced analytically to the point where only simple algebraic manipulations are required of the 650.

212' Electrical Engineering. Field Due to a Source in Magneto-ionic Media. The numerical evaluation of a set of definite integrals representing the fields due to a current source in a magneto-ionic medium is to be carried out. The integral which cannot be performed by analytical means is, however, quite suitable for numerical evaluation through the use of a computer. It contains sine, cosine, exponential and Bessel functions for which standard library routines exist.

The near field information is necessary for evaluating the performance of an antenna mounted on a rocket which is flying through the ionosphere.

213' Civil Engineering. Time-Dependent Deflections of Prestressed Concrete beams. This problem is to determine the time-dependent deflections of prestressed concrete beams. It involves the numerical integration of

$$C = \int_{t_1}^{t_2} f_c \frac{dc}{dt}\, dt$$

where

C = Total strain

f_c = Stress (a function of t)

$\frac{dc}{dt}$ = Creep function (creep per unit stress as a function of time)

214'T Agronomy. Relationships Among Agronomic Characteristics of Alfalfa. This thesis problem involves a study of the possible relationships among such agronomic characteristics of alfalfa as yield, number of plants per unit area, number of shoots per plant, root diameter, height of plant, and weight per plant under various conditions as imposed by the treatments. These treatments

include several methods of seeding, several methods of fertilizer placement, several levels of companion crop competition and several locations. The experimental design is a randomized complete block. Analysis of variance, covariance, and multiple covariance techniques including single degree of freedom comparisons will be used to evaluate the effects of the treatments themselves and the relationships of the above enumerated characteristics.

215' Agricultural Economics. X^2 Consist. 2 Way % Table. The purpose of this study is to determine the pricing structure for hogs sold in Illinois.

The International Business Machines 650 can be utilized advantageously to compute the consist (percentage of hogs sold in each weight class) of all hogs sold in the Chicago and St. Louis markets and in the country markets of Illinois.

Two-way tables which will show the number, raw per cent and column per cent of hogs in ten weight classifications and twenty-six price classifications will be made.

216'T Economics. Multivariate Analysis of Response Errors. The study is to determine the factors influencing the distribution of response errors.

A sample size of 1800 will be used and 33 variables will be analyzed. These include response errors in total loan, principal loans, monthly payments, and some characteristics of respondents and interviewers such as age, sex, education, income level, region, family compositions, amount of experience of interviewers, etc.

Chi-square is used to test the hypotheses of absence of relationships between the three error variables and the characteristics of respondents and interviewer.

Having established the importance of each factor by X^2 analysis, regression analysis will be used to determine the relative importance of the factors in influencing the distribution of the errors.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of February.

TABLE I'

		Hrs:Min		
Scheduled Engineering		13:23		
Unscheduled Engineering		21:04		
Agronomy Library		:31		
DCL Library		6:33		
Classes				
CE 391	:02			
Math 365	1:46			
Demonstrations		3:08		
Wasted		2:40		
			49:07	

Use by Departments

Agricultural Economics		13:29		
Agronomy		15:45		
Animal Science		3:47		
Astronomy		:45		
Chemistry		16:41		
Civil Engineering		14:32		
Digital Computer Laboratory		:51		
Electrical Engineering		4:06		
Graduate College		16:08		
Mechanical Engineering		14:23		
Mining and Metallurgical Engineering		:50		
Physics		:49		
Psychology		:08		
Small Homes Council		:31		
State Water Survey		9:22		
Statistical Service Unit		128:17		
Admissions and Records	5:35			
Agricultural Economics	:50			
Agricultural Extension	2:41			
Bur. of Business Management	1:50			
Bur. of Educational Res.	2:27			
Bursar's Office	6:55			
Business Office	19:00			
DHIA	32:23			
Economics	2:28			
Education	37:14			
Forestry	:18			
Horticulture	3:28			
Marketing	:43			
Psychology	4:02			
Statistical Service Unit	2:54			
Student Counseling Service	5:29			
Theoretical and Applied Mechanics		:07		
			240:31	
				289:38

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 10:00 p.m. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for February.

TABLE III'

533		11
Board	1	
Fails to read	2	
Fails to punch	1	
Card jam	1	
Cards off punched	1	
False end of file	2	
Reads incorrectly	3	
650		10
Blank or multiple bits	9	
Hang ups on legal orders	1	
Tape, Tape Unit, Tape Control		10
Hang ups on legal orders	2	
Rewinds improperly	2	
54 orders always go to I address	1	
Tape rewinds before end of file	3	
Low voltage	1	
Not determined	1	
653		3
Blank or multiple bits	2	
Not determined	1	
655		1
Power failed to come on	1	
Total		35

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
2/1/61	13:15			:07	3	(1) Double bits in pos. 10 of the dist. and upper acc. (2) Last quinary bits in pos. 7 of dist. (3) Bad wire on 533 board.
2/2/61	2:57		10:00	:04	4	(1) Console hangs up on 068010 when program runs but runs okay if half cycle through order. (2) Multiple bits in pos. 2 of the dist. (3) Blank bits in core location 9013. (4) 533 fails to read. Found a bad clutch coil.
2/3/61	13:25		2:23		5	(1) 533 fails to read. Bad relay point found. (2) 533 would not punch. (3) Multiple bits in pos. 3 of dist. (4) Card off punched in middle of output (5) Card jam in 533 punch.
2/6/61	9:16	3:43	(:30)*	:01	1	(1) Distributor gets multiple and blank bits.
2/7/61	13:06		:07	:04	1	(1) Tape unit 1 does a high speed rewind instead of a low speed. Light adjusted.
2/8/61	16:01			:06	2	(1) Multiple bits in dist. Positions 2 and 6. (2) 54 orders always going to I addresses instead of D addresses.
2/9/61	12:58			:07	0	
2/10/61	12:55			:11	0	
2/13/61	11:56	2:00		:04	1	(1) End of file read on tape when there was no end of file. Tape rewinds in middle of run.
2/14/61	16:44			:05	3	(1) Invalid information read into core storage. (2) Card feed stops on end of file when no end of file. (3) Tape unit 2 jumped the tape in a re-wind.
2/15/61	13:43		1:24	:04	2	(1) Col. 19 did not read from cards. (2) Seven dist. errors resulting in blank or multiple bits.
2/16/61	14:49		1:02	:17	1	(1) Power would not come on due to a dirty contact in 655.

TABLE II' (Continued)

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
2/17/61	15:41			:19	1	(1) Four dist. errors - multiple bits from 0001 and 0009.
2/20/61	10:11	3:50			0	
2/21/61	14:11			:15	3	(1) All three tape units rewound in middle of tape when they shouldn't. (2) Had 15 hang ups due to 533 misreading various columns of word one. (3) 533 read card incorrectly.
2/22/61	10:56		2:55	:09	5	(1) 06 orders hung up. (2) 2 hang ups on shift orders. (3) Multiple bits in pos. 0009. (4) Tapes rewound when they should not have. (5) Storage unit error. Replaced tubes in 653.
2/23/61	10:44		3:13	:06	2	(1) 15 storage unit errors. Found low voltage in 652. (2) Tape unit not operating properly. Bad tube in 652 found.
2/24/61	14:53			:10	0	
2/27/61	11:09	3:50		:01	1	(1) 533 giving false end of file lights.
2/28/61	13:41			:30	0	
						*Repair time spent on a unit which did not stop the running of the 650. Time is not counted in the total.
TOTALS	252:31	13:23	21:04	2:40	35	

PART VIII

GENERAL LABORATORY INFORMATION

Seminars

"The Numerical Evaluation of Functions Defined by Laplacian Integrals", by Professor Peter Henrici, Associate Professor of Mathematics, University of California, Los Angeles, California, February 13, 1961.

"An Optimum Procedure and a New Library Routine for the Numerical Solution of Ordinary Differential Equations", by Professor Arnold T. Nordsieck, Research Professor of Physics, Physics Department, University of Illinois, Champaign, Illinois, February 20, 1961.

"An Optimum Procedure and a New Library Routine for the Numerical Solution of Ordinary Differential Equations" (Part II), by Professor Arnold T. Nordsieck, Research Professor of Physics, Physics Department, University of Illinois, Champaign, Illinois, February 27, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	10	1	10.75
Visiting Faculty	0	0	--
Research Associates	2	0	2.00
Graduate Research Assistants	10	25	23.75
Graduate Teaching Assistants	0	5	2.00
Administrative and Clerical	6	1	6.33
Other Nonacademic Personnel	40	15	45.33
Totals	68	47	90.16

The Laboratory Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbaum, J. E. Robertson, and J. N. Snyder.

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DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - CIRCUIT RESEARCH PROGRAM

PART III - MATHEMATICAL METHODS

PART IV - DATA REDUCTION METHODS

PART V - ILLIAC USE AND OPERATION

PART VI - IBM 650 USE AND OPERATION

PART VII - GENERAL LABORATORY INFORMATION

March, 1961

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Physical Aspects of Machine Construction

The following small parts orders are complete:

Center telephone poles	(A-2001)	1000 units
End telephone poles	(A-2002)	2000 units
Terminal strips	(B-2003)	1000 units
2N706 heatsink	(A-2004)	500 units
2N1072 heatsink	(A-2005)	1000 units

The main frame for the section of the computer that includes the main arithmetic unit, flow-gating, delayed control and advanced control has been completed and is in place on the computer room floor.

Shop progress is as follows:

66 chassis completed
17 in wiring stage
7 held up for parts
3 waiting for diodes.

(C. E. Carter, S. Krabbe and H. E. Lopeman)

2. Layout of the Arithmetic Control

It is generally understood that the layout of control logic can materially affect the speed of the machine. Therefore, in an attempt to obtain the optimum speed, the control is being laid out in a 4-step process. Initially a general layout was made in which large (100 to 600 transistors)

subsections of control were assigned to chassis locations. The figure of merit calculations discussed last month were used as a guide in this step. Secondly, the various general layouts were evaluated and one selected. This was then refined to designate much smaller subsections of control (10 to 100 transistors). This refined layout specified the sublocation within each chassis assigned to the sequencing control areas, to the selector control logic, for status memory elements, and also allowed space for logic necessary to combine requests and distribute replies. The third step in the process was to draw out the logic required to combine requests and distribute replies for each gate and selector used. This comprises about 15 separate layouts. The final step then was to make the actual chassis layout drawings. The work has progressed to the point where the chassis layouts for the EAU (exponent arithmetic unit) and most of the end connections are being made or are done, however, the remainder of the layout must be redone. This rework is due to excessive lead lengths encountered while doing the third step mentioned above. These long leads necessitate use of restoring circuits to combine requests and distribute replies whereas the first attempt assumed nonrestoring logic. Since the inclusion of restoring circuits in the request and reply paths will require more transistors and also longer time per basic operation, a second iteration in the step-by-step layout process will be required. This second iteration will be carefully done in the belief that it will be the final one.

Any reduction in the number of transistors required by delayed control or elimination of request and/or reply lines would obviously aid the second layout mentioned above. As a result, it is proposed that the selectors into the A and Q registers be driven by one control rather than by two as is presently done. A similar thing will be done for the S and R registers. As a result the four replies sAr, sQr, sSr and sRr would become two; namely sAQr, sSRr. In addition each request would accomplish two operations; e.g. (1/4 AsS, 1/4 QsR) or (AsR, QsS) or (AsR, OsS) etc; and also about 80 transistors would be eliminated from the selector control logic. The price paid for this simplification is that there would be less

flexibility available for future expansion of control and also three infrequently used instructions LDQ, STQ and STX would take slightly longer to perform. The following is a list of the selector options available under this new plan.

S and R Register Selector Inputs

Designation	Operations Performed	Description
OsSR	OsS, OsR	Zero selected into both registers
RSsSR	1/4 AsS, 1/4 QsR	Right shift into both registers
LSsSR	4 AsS, 4 QsR	Left shift into both registers
INTsSR	AsR, QsS	Full interchange
INTZsSR	AsR, OsS	Half interchange, zero selected into S

A and Q Register Selector Inputs

Designation	Operations Performed	Description
OsAQ*	OsA, OsQ	Zero selected into both registers
RSsAQ	1/4 SsA, 1/4 RsQ	Right shift into both registers
LSsAQ	4 SsA, 4 RsQ	Left shift into both registers
SDsAQ	SsA, RsQ	Straight down into both registers
SZsAQ	SsA, OsQ	Straight down into A, zero into Q

* At present this option is not used and it may be eliminated; however, its inclusion may bring some interchangeability.

(H. Aiso, J. O. Penhollow and R. E. Swartwout)

3. Advanced Control

The register and selector arrangement was finalized during the month, and logical design was begun on the larger areas. A generalized 13-bit assimilated sum and the AND and EXCLUSIVE OR functions was designed in 3 ways.

(a) An adder with level-restored outputs and a maximum of 2 collector delays between the input signals and the output signals.

(b) A one-collector-delay adder with single outputs.

(c) A one-collector-delay adder with complementary outputs in every digital position.

These required respectively 242, 415 and 506 transistors, and the simplest adder was chosen.

There are two general ways of implementing 13-bit binary shifts in the address arithmetic unit. The first requires a 4-bit counter with zero-detection equipment, an additional gated entry to one of the 13-bit registers AA and AS, and a two-step loop in advanced control complete with an exit flipflop to sequence the operations. The second method involves the use of 2 selectors in cascade (either a 4-way selector and a 3-way selector or 2 4-way selectors). The advantages of the second method are that slow circuits can be used and the operation time is about 20 times as fast. The disadvantage is that more transistors are required. The first method requires about 140 fast transistors while the second requires 240 slow transistors and 55 fast transistors. The second method has been chosen.

A preliminary study has been made of the control counter. It appears that slow logic can be used for it, and the design has been begun.

Flow charts for order fetching, address preparation, and the execution of other advanced control orders are partly done, and have been used in evaluating the set of advanced control orders. Some changes have been made in the 13-bit arithmetic orders.

(M. Faiman, D. B. Gillies and R. R. Shively)

A number of ways of using "busy" flipflops in a speed-independent control have been designed. The more complex designs are needed in those places in which parallel operations must proceed as far as possible before waiting because of a busy flipflop, and must resume operation as soon as possible after the flipflop ceases to indicate that equipment is busy.

(C. S. Wallace)

4. Description of MAU Test Control Operation

The MAU Test Control exercises all gates and all possible selector paths except the "carry generator to A-adder" path in the repetitive sections of the MAU. Due to limited power supplies, tests are restricted at present to a 2 (base 4) digit section consisting of one QRM, A, and S chassis each, together with appropriate Driver-Drivers.

The test sequence consists of the following steps:

$\overline{2M}$sS, SsA, RsQ
gA, gQ
$\overline{M}$sA, 1/4AsS, 1/4QsR
gS, gR
$\overline{M}$sS, 4SsA, 4RsQ
gA, gQ
2MsA, 1/4AsS, 1/4QsR
gS, gR
2MsS, SsA, RsQ
gA, gQ
MsA, 4AsS, 4QsR
gS, gR
MsS, 1/4SsA, 1/4RsQ
gA, gQ
2MsA, 4AsS, 4QsR
gS, gR
OMsS, SsA, RsQ
gA, gQ
OMsA, AsR, QsS
gS, gR
RgM

The following comments are worth noting:

During the last step, the output of the A-adder is gated into R and from there into M. The output is assimilated without using the carry generator by adding zero in the next to last and in the last step, since one carry storage position is assimilated each time zero is added.

All shifts, additions, and carry propagations are performed in an end-around fashion so that indeed all digital positions and transfer paths are checked. As a consequence, the operation of the MAU under this test is modulo 15, equivalent to operation in the one's complement representation.

(If more digital positions are to be tested simultaneously, they must be connected end-around chassis by chassis, with each section operating mod 15, if the two "add zero" steps of the present sequence are to suffice in general for assimilation.)

The net effect of the test sequence exclusive of the last step is to add (M) to (S) and place the result into A, as well as place (R) into Q. The last step interchanges (A) to R, and (Q) to S, and furthermore transfers (R) to M. Thus, if the sequence starts with a_0 in Q and S, a_1 in A, R, and M, the following table results:

	(A)	(S)	(Q)	(R)	(M)
Initial Contents	a_1	a_0	a_0	a_1	a_1
Effect of Steps 1-9	a_0+a_1		a_1		
Effect of Last Step		a_1		a_0+a_1	$a_0+a_1 \equiv a_2$
Effect of Steps 1-9	a_1+a_2		a_2		
Effect of Last Step		a_2		a_1+a_2	$a_1+a_2 \equiv a_3$
Effect of Steps 1-9	a_2+a_3		a_3		
Effect of Last Step		a_3		a_2+a_3	$a_2+a_3 \equiv a_4$
Etc.			Etc.		

Clearly, the successive contents of individual registers form a Fibonacci series. Because addition is performed modulo 15, the Fibonacci series will be cyclic. The following Fibonacci cycles, defined by their first two terms a_0 and a_1, obtain for modulo 15 addition:

	a_0	a_1	No. of Terms In Cycle
Cycle I	0	1	40
II	0	2	40
III	0	3	20
IV	0	4	40
V	0	5	8
VI	2	1	8
VII	1	8	8
VIII	0	8	40
IX	4	2	8
X	3	9	4
XI	8	4	8

Together with "cycle" $a_0 = a_1 = a_i = 0$, all 225 possible combinations of two numbers mod 15 are accounted for.

In summary, there are

4 cycles of length 40
1 cycle of length 20
5 cycles of length 8
1 cycle of length 4
1 cycle of length 1

Characteristic patterns can be derived for the different digital positions and operation of the unit can be checked by observing the pattern on an oscilloscope.

(C. E. Carter, M. Melman, G. Metze)

Work has been started on drawing up a D.C. check-out procedure for the S, A, QRM (MAU) chassis. All D.C. voltages appearing at all emitter, base and collector connections have been tabulated for the S, A chassis, and measurements have been checked on one chassis (A).

(A. P. Stone)

5. Slowed Down Operation Tests

Measures necessary to ensure correct operation of control points, discussed in File No. 353, "Threshold Uncertainty and its Effect on Control Circuit Design", have been incorporated in the control points of the MAU test control. In order to test their effectiveness, capacitors as large as 10 μfd were connected between ground and the signal leads to the two control points. Operation of the unit was slowed down about 7000 times. (During normal operation, successive gates in the MAU, e.g. gA, occur every 670 nsec.) The unit ran reliably at the slowed down rate, although noise caused partial switching of the restoring AND circuit as the signal slowly approached the switching threshold. The partially switched output caused no ill effects in this particular design which smoothed the signal since it was fed to another restoring circuit.

(G. Metze, M. Melman and K. Mikami)

6. Slow Circuits

Data were taken and compiled during March from which spread curves for the two types of zener diodes used in slow circuits were generated. A set of acceptance specifications was written from these data.

The diode curves were opened up in an effort to make them inclusive of many types of inexpensive diodes.

The N250-N251 curves are being modified to make them more representative of units being received.

Investigation is continuing in the use of transistors other than N250's in slow circuits in order to slow them further in places where slower speeds are necessary.

(M. D. Freedman and L. J. Peek)

7. Core Storage Unit

An air blower which will be used to cool the magnetic switches in the core stack was received during this month. This blower, when attached to the model memory, allows a temperature rise of only 7-8^{o} C in the air space. However, the air velocity in the immediate vicinity of many of the switch cores is low. Therefore, the switch material may rise to an estimated 70^{o} or 80^{o} C above ambient when the corresponding word is accessed at the maximum rate (667 kc/s).

The model memory is being run on "heat cycling" by which is meant that a randomly selected word is accessed at maximum rate for, typically, 3 seconds, thus heating the switch core (and storage cores, also) to nearly the maximum temperature. A 48-hour error-free run was accomplished under these conditions.

(S. R. Ray)

An automatic resetting device was installed and modified so that, with a recording voltmeter, it now provides a true log, recording error-times, on-time, off-time, and forced power turn-off times.

A thermistor-controlled device which monitors core-stack temperature and turns off power at a selected value was designed, constructed, tested, calibrated, and installed.

Some design and material testing was done on a project to build a 10 kw, water-cooled, low-voltage resistive load for power supply testing.

(Bruce E. Briley)

Consideration has been given to the equipment which will be necessary to test the final version of a 4096-word core memory after it has been wired and mounted in its frame. It is planned that the control counter necessary as a part of advanced control will be available at the same time as the 4096-word core memory is completed in order to have a source of addresses available to the memory.

A block diagram outlining the equipment and interconnections necessary to test a 4096-word core memory has been drawn.

(John L. Muerle)

8. Magnetic Drum Memory

Further study is being made on the choice of transistors and the design of the head selection switch. A one-bit section of the 4 x 8 matrix switch is shown in Figure 1. The row and column select transistors are saturating PNP's. They should carry the high write and low read currents with low and constant V_{CE} and with nearly constant I_B. Switching speeds can be slow, because selection is done in the sector gaps.

The write amplifier output transistors are fast NPN's. Dissipation during switching is high due to the inductive load. The worst case is writing alternate 1's and 0's (50% duty cycle for each transistor).

The important transistor requirements are as follows:

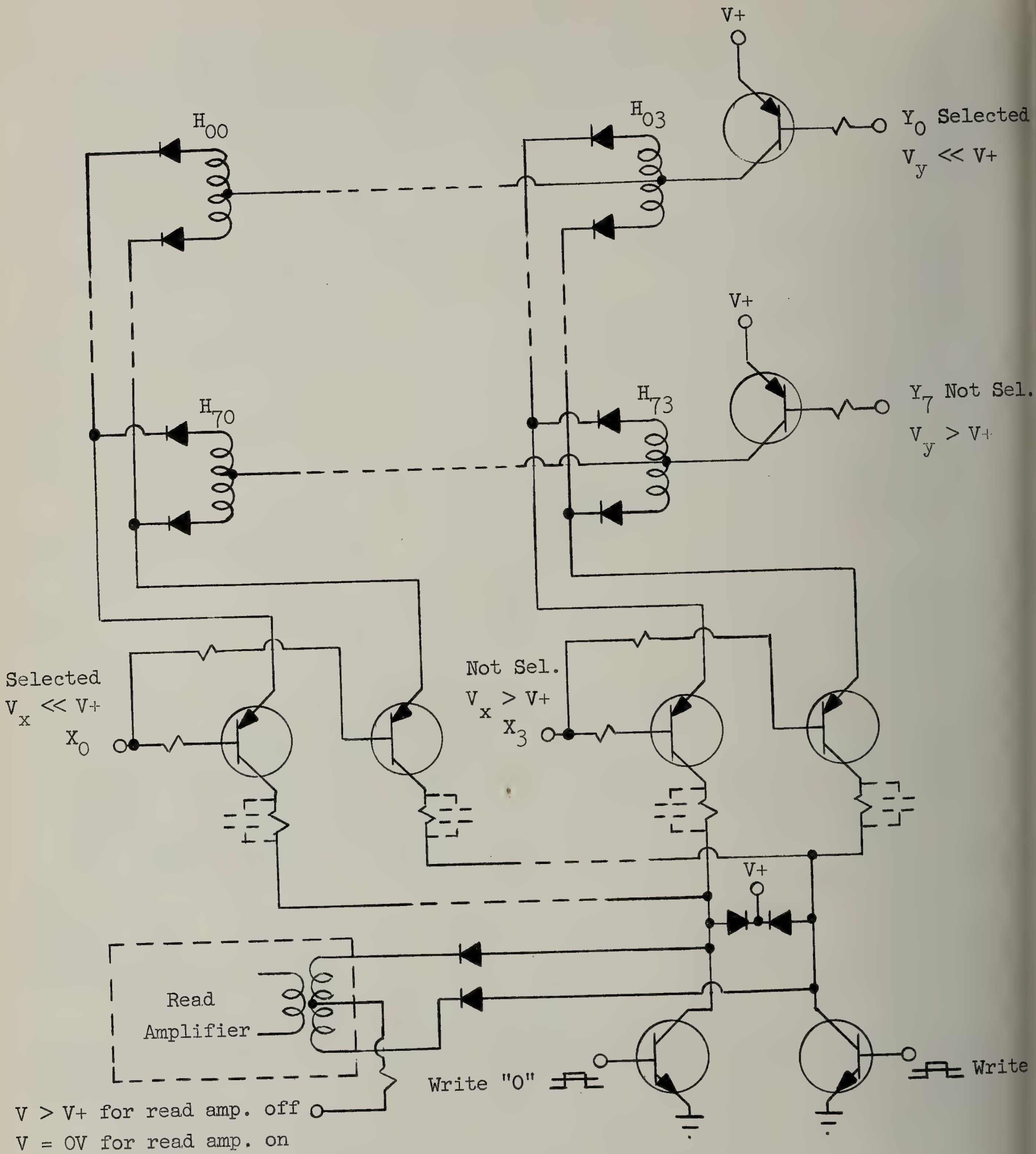


Figure 1

Magnetic Drum Head Selection Circuit

	PNP	NPN
V_{CE} max.	35-50 v	35-50 v
V_{CB} max.	35-65 v	35-65 v
V_{BE} max.	5-10 v	5-10 v
I_C continuous	> 120 ma	> 120 ma
Dissipation (45° C case temperature)	1-1.2 w	0.8-1.0 w
h_{FE} (V_{CE} = 1 v, I_C = 120 ma)	15	15
V_{CE} (sat)	0-2 v	0-2 v
V_{BE} (sat)	0-2 v	0-2 v
Delay, rise, storage, fall times	-	40-60 nanosec. each

A number of transistors of both types have been tried out. Final selection will be made after more experiments.

Head selection diodes should carry the write currents with low and constant voltage drop. Recovery speed need not be great, since recovery takes place in the sector gap.

The circuit associated with the selected head is shown in Figure 2. An experimental circuit consisting of half of Figure 2 was set up to measure switching speeds. A 50 μh inductance was usedin place of one leg of the read-write head. It was found that:

(1) Writing speed is not limited by the slow X and Y select transistors. The fast NPN transistor can vary the current through them much faster than their delay, rise, storage and fall times indicate.

(2) The Y select voltage swing need not be as large as the write voltage swing across the head.

(3) Current rise times of the order of 400 nanosec. are attainable with a supply voltage of 25 volts and a steady state current of 125 ma. When a 40 volt supply is used, this is reduced to around 250 nanosec.

(P. V. S. Rao)

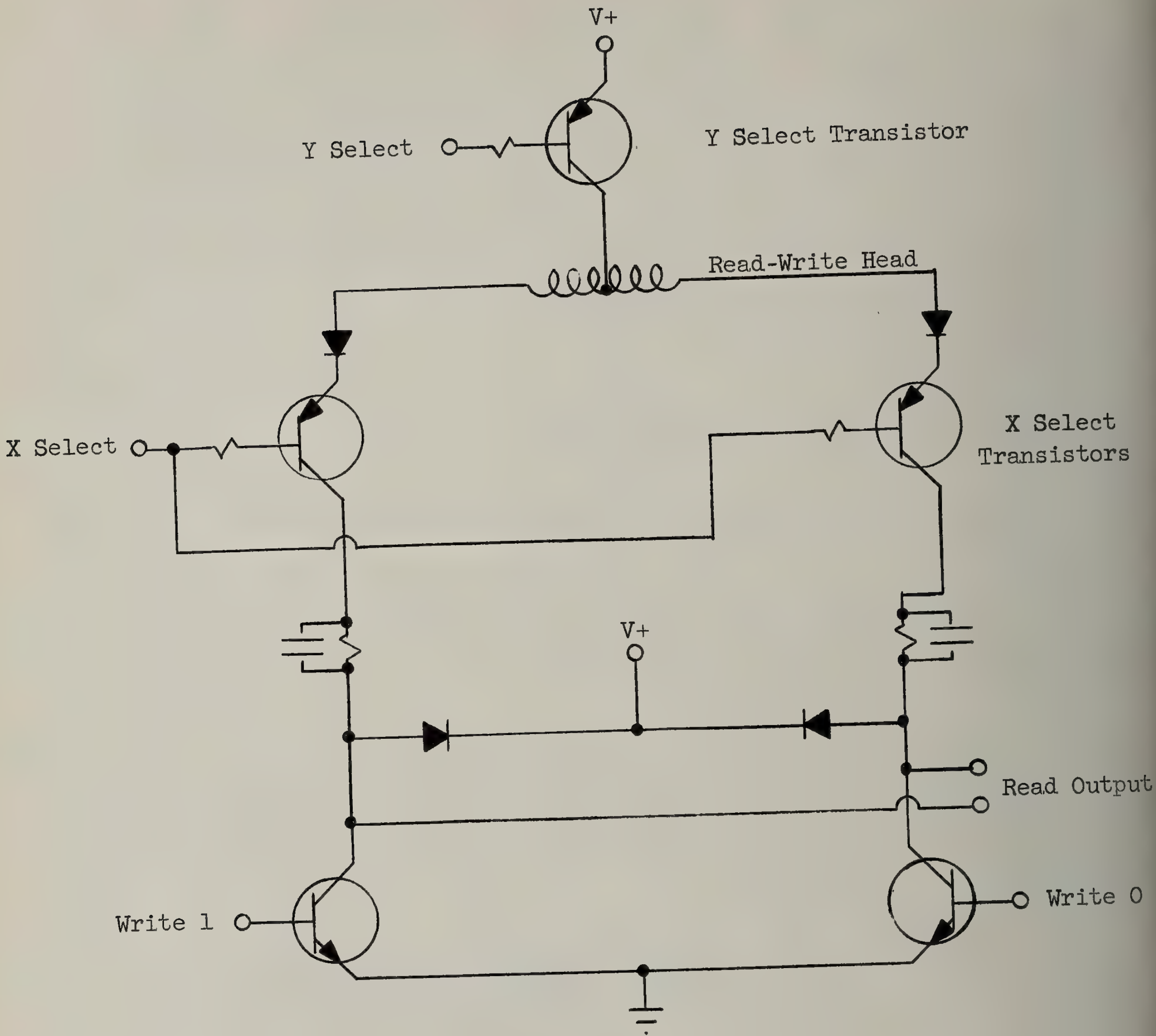


Figure 2

Circuit Associated with the Selected Head

A drum head write amplifier for use in write-read experiments was designed and tested, as shown in Figure 3. This circuit will drive up to 120 ma into a head of 40 to 50 μh with a rise time of 250 nanosec.

(C. N. Liu)

The investigation of transformer-coupled and resistor-coupled read amplifiers using the N250 transistor was begun.

(H. Yazaki)

9. Magnetic Tape Memory

It was found that the base-7 conversion (discussed in the February, 1961 Progress Report) can be effected by a serial process with efficient use of equipment. By including some gates governed by the type of operation to be performed - encode or decode - about 75% of the circuit elements can be used in both encoding and decoding. In either process, the result is formed as one three-bit digit per circuit operation, so that four operations are required per tape character.

No detailed logical diagram has yet been made, and it is not known at what repetition rate the system can be operated.

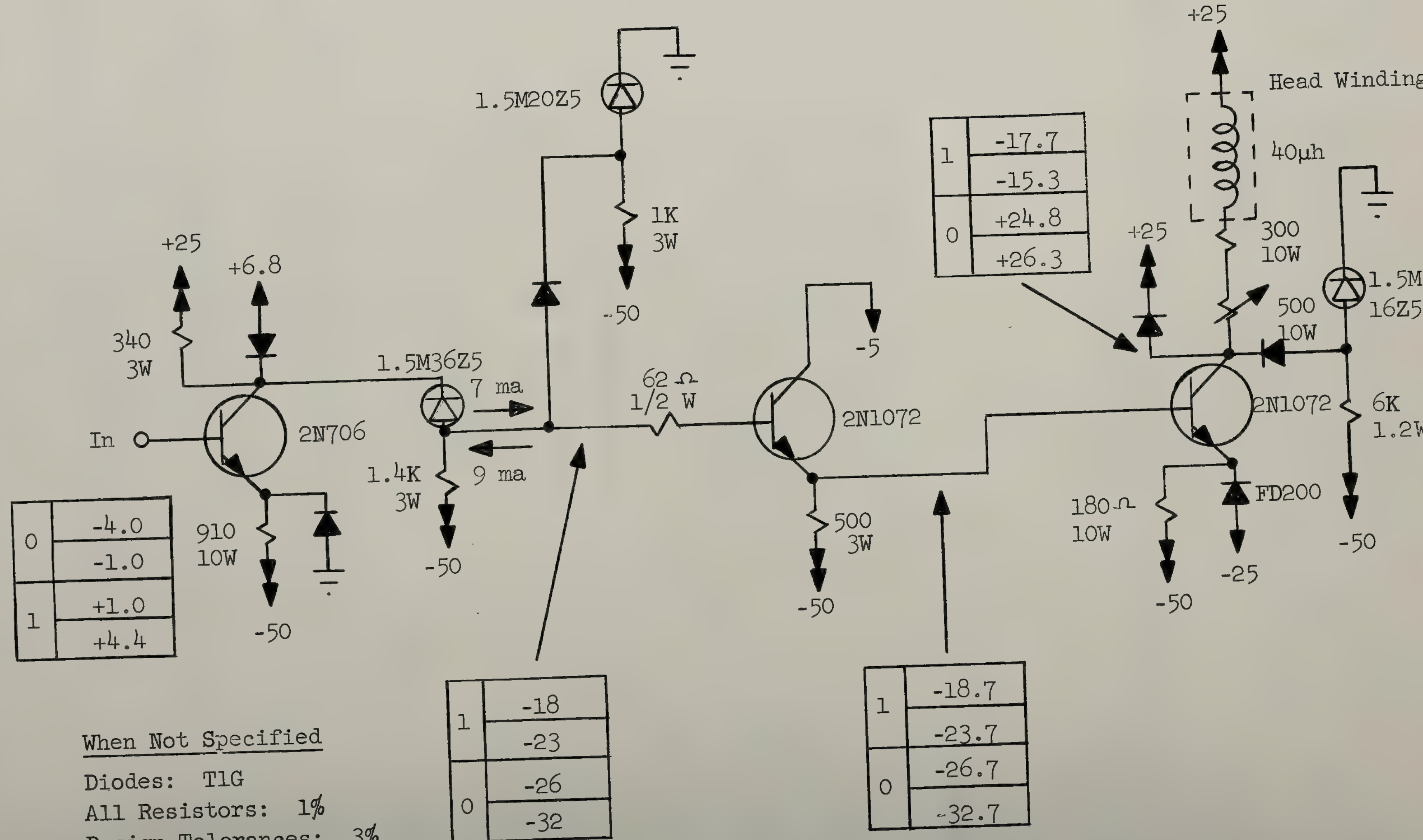
(R. L. Cummins)

10. Paper Tape Equipment

An Elliot reader has been ordered, for delivery from stock. This reader can stop the tape from 1000 cps in 0.033 in., which is about twice as good as we need.

Block design of the reader and punch circuitry are complete, and detailed logical design using the slow circuit elements has begun.

(C. S. Wallace and personnel of the Coordinated Science Laboratory)



When Not Specified

Diodes: T1G

All Resistors: 1%

Design Tolerances: 3%

Figure 3

Drum Head Driver

11. December, 1961 Input-Output Arrangements

Due to some recent simplifications of A.C. design, the arrangements for non-autonomous input-output have to be changed somewhat. A single transistor word register for assembly and dissection of drum words will be needed, which will receive words for output from flow-gating, and deliver input words directly to the core memory. The same register will be used for paper tape operations, which will be done on a character-by-character, rather than block, basis.

(C. S. Wallace)

12. Transistor Testing

Two instruments are being designed and constructed:

(1) α-plotter - an instrument whose purpose is to display $(1-\alpha_{DC})$ vs log I_E, parameter V_C. It is to be used as an extension of the Tektronix Curve Tracer.

(2) Junction Temperature Meter - for the purpose of measuring the collector-base junction temperature of transistors under various conditions of DC power dissipation and cooling.

This will be used to compare GF45011, S166, 2N559, 2N705, etc., with and without cooling fins.

(S. T. Ribeiro)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

R. Crow continued his work on base-current transients during high-speed switching. C. Afuso examined the behavior of a switching amplifier used as a load for another switching amplifier. H. Guckel worked on the geometrical layout of a very fast shifting register and the associated gate-driver. The first two items are reported on in more detail under Sections 2 and 3.

2. Base Current Transients

A third circuit for the measurement of the transient base current in a switching amplifier, including the effects of the diode enhancement current, is shown in Figure 1. The local power supply filters are not shown. With no input from the pulser, the transistor is on and the diode off. To switch the current into the diode, the

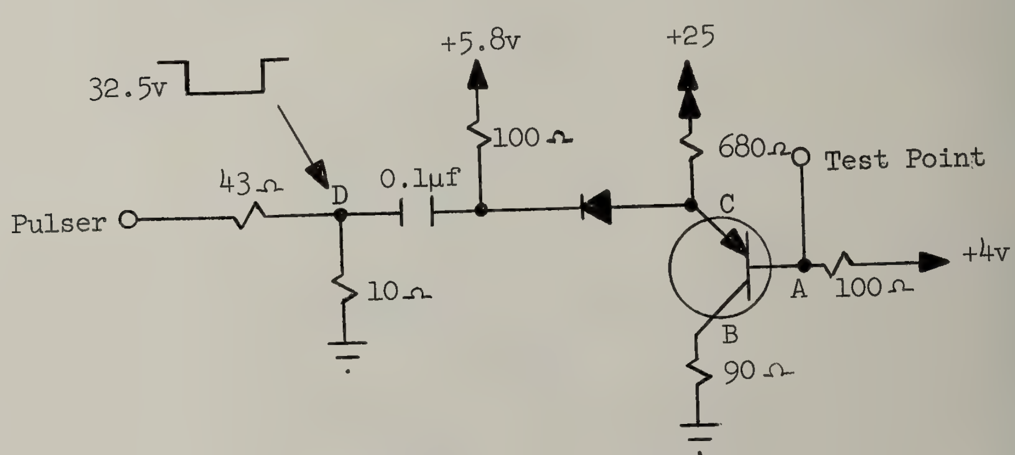


Figure 1

Arrangement Used to Study Base Transients

pulser brings the cathode of the diode down to ground. Typical ON voltages are B = 2.7 v, C = 4.6 v. 100 ohms base impedance was chosen for correlation with the "difference voltage" method described previously. A sketch of the input waveform, showing its rise time and overshoot is shown in Figure 2. With the high bandpass of the Lumatron, one finds that it is difficult to get perfectly clean large amplitude pulses. The pulse width at the input was 35 mμsec.

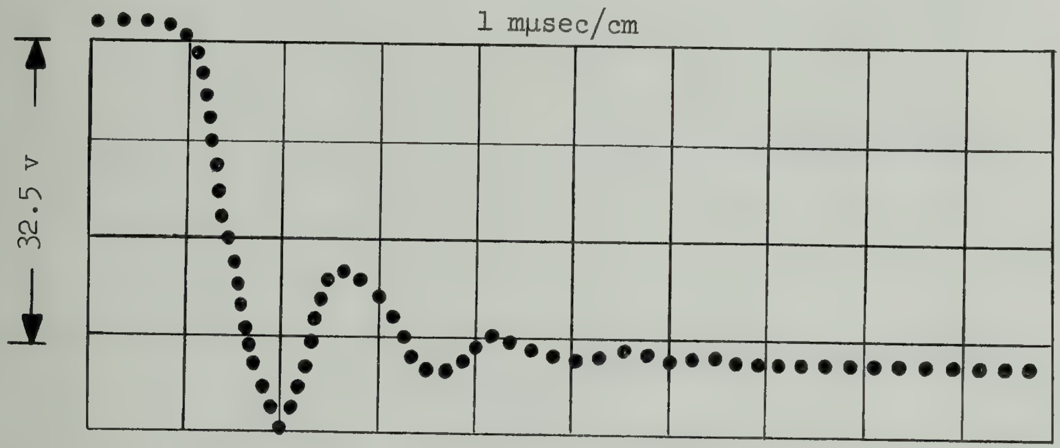
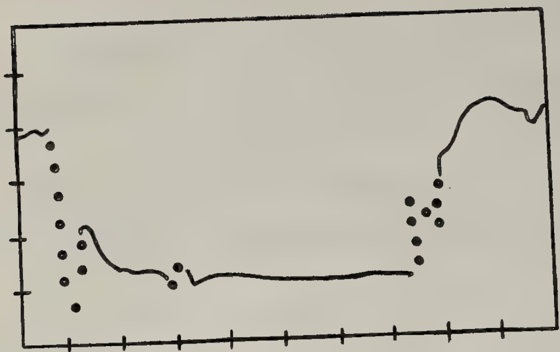


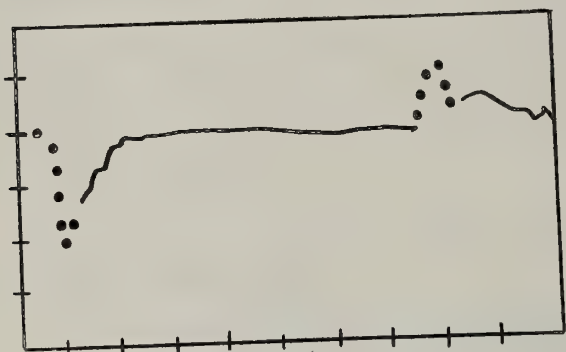
Figure 2

Input Waveform of the Circuit in Figure 1

Figure 3 shows the collector waveform and the over-all base current transient of a typical GF45011 (TR #2). Figure 4 is a detailed look at the turn-off and turn-on transients. The peculiar collector current waveform of TR 6, Figure 5, was noticed on 3 of 4 GF45011's in "gold cases" which were observed. The 4 "black cased" GF45011's which were observed all had collector waveforms similar to Figure 3, but considerable difference between base currents (in shape, not peak amplitude) was in evidence. Table 1 shows DC data on the two samples.

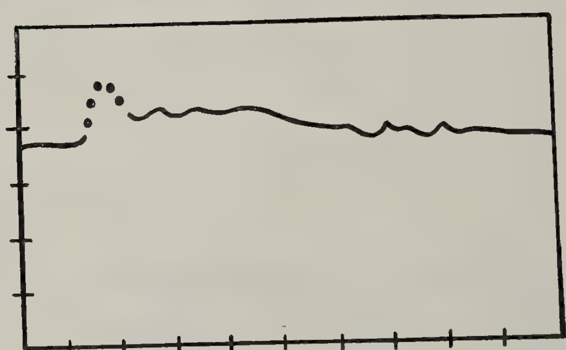


TR #2 - (Black Case)
Collector Waveform
1 v/cm 5 mμsec/cm

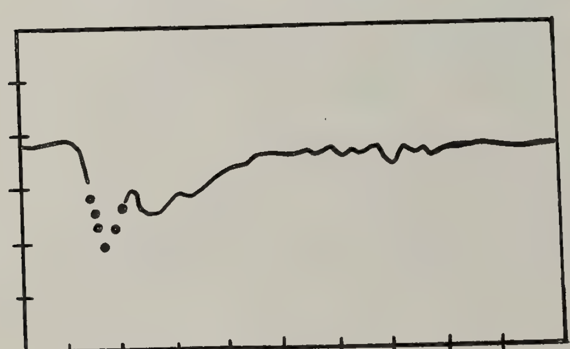


TR #2
Base Current Transient
10 ma/cm 5 mμsec/cm

Figure 3
Collector and Base Transients for a New GF45011 at 30 ma

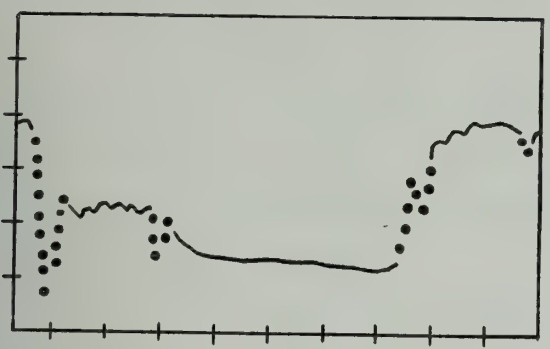


TR #2
Turn On Base Current
10 ma/cm 2 mμsec/cm

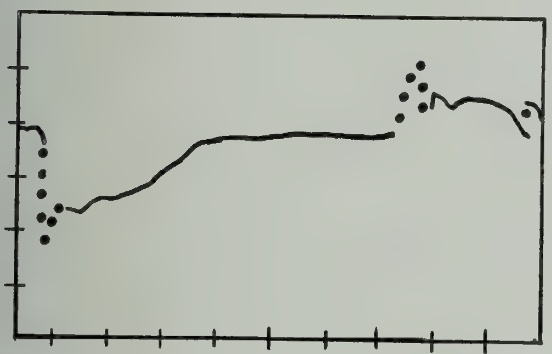


TR #2
Turn Off Base Current
10 ma/cm 2 mμsec/cm

Figure 4
Details of the Base Transients for a New GF45011 at 30 ma



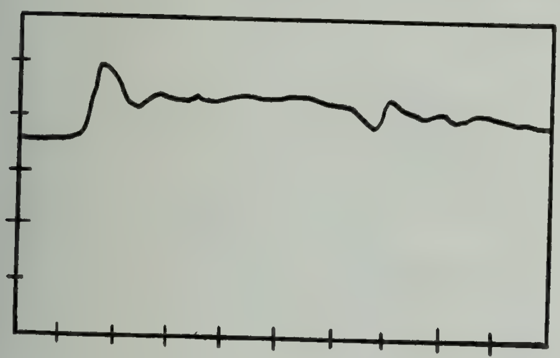
TR #6 - (Gold Case)
Collector Waveform
1 v/cm   5 mμsec/cm



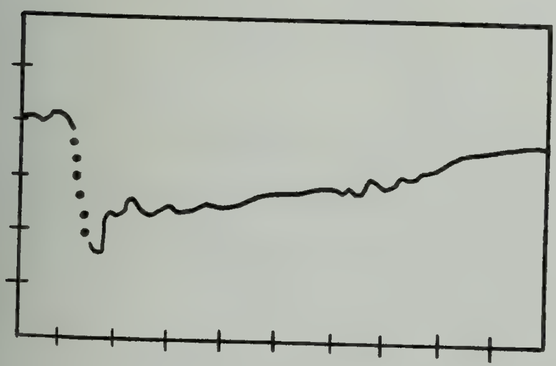
TR #6
Base Current Transient
10 ma/cm   5 mμsec/cm

Figure 5

Collector and Base Transients for an Old GF45011 at 30 ma



TR #6
Turn On Base Current
10 ma/cm   2 mμsec/cm



TR #6
Turn Off Base Current
10 ma/cm   2 mμsec/cm

Figure 6

Details of the Base Transients for an Old GF45011 at 30 ma

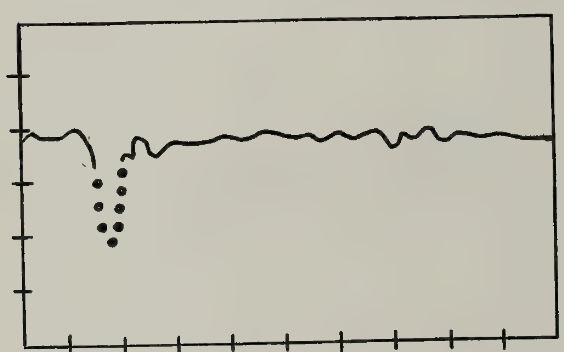
Table 1

Data Taken for I_E = 20 ma V_{CB} = 2 v

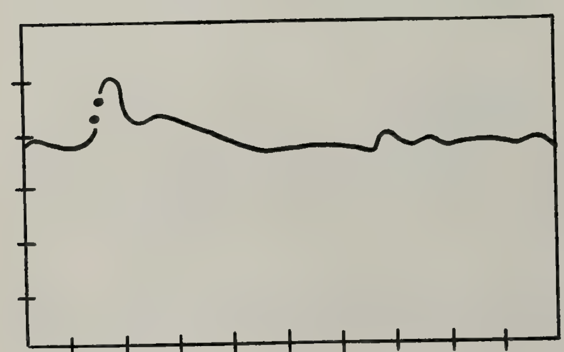
	α_{DC}	V_{BE}
TR #2	0.905	0.11 v
TR #6	0.935	0.11 v

The current being switched by the transistor in Figure 1 is about 30 ma. Figure 7 shows the base current when the 680Ω emitter load is replaced by a 1.3 K resistor. This changes the switching current to 15 ma.

Figure 4 should be compared to the "difference voltage" measurements described previously for correlation. The two methods agree reasonably well as to shape, but the amplitudes differ appreciably, especially for the turn-off case. It is believed that the last method described here is the most desirable of those discussed.



TR #2
Turn Off Base Current
680Ω Resistor Changed to 1.3K
10 ma/cm 2 mμsec/cm



TR #2
Turn Off Base Current
680Ω Resistor Changed to 1.3K
10 ma/cm 2 mμsec/cm

Figure 7
Details of the Base Transients for a New GF45011 at 15 ma

3. <u>High Speed Difference Amplifiers</u>

It has been tried to find the optimum condition for high speed operation of the system of difference amplifiers based on the data obtained last month. Since the data was obtained for an unloaded difference amplifier, the test, this time, was done with a difference amplifier load in the form of the next stage.

It was found that the input impedance of the difference amplifier was quite low during the transient. The rise time and fall time when another difference amplifier is connected now became about 4 mμsec. The rise time was 0.6 mμsec. and the fall time was 1.5 mμsec. in the unloaded case.

In order to make the input impedance higher, a new method was tried: a transformer. As shown in Figure 8 the result was not satisfactory. For several L_1's and L_2's experiments were run, but in all cases fairly strong high-frequency oscillations were observed.

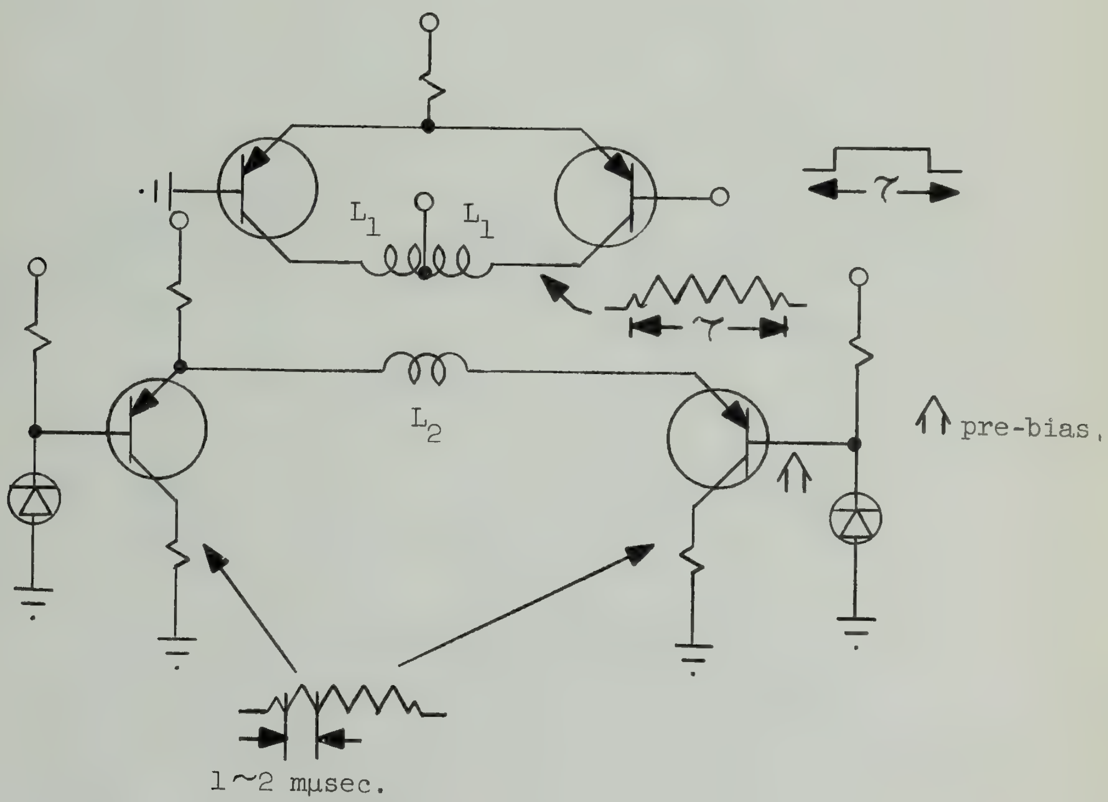


Figure 8
Transformer Coupled Difference Amplifier

The only way of improving the low impedance difficulty would seem to be preceding each transistor by an emitter-follower. The circuit for this case is shown in Figure 9.

The result was satisfactory:

Rise time	Fall time
0.6 mμs.	1.0 mμs.

for v_0 and $\bar{v}_0$.

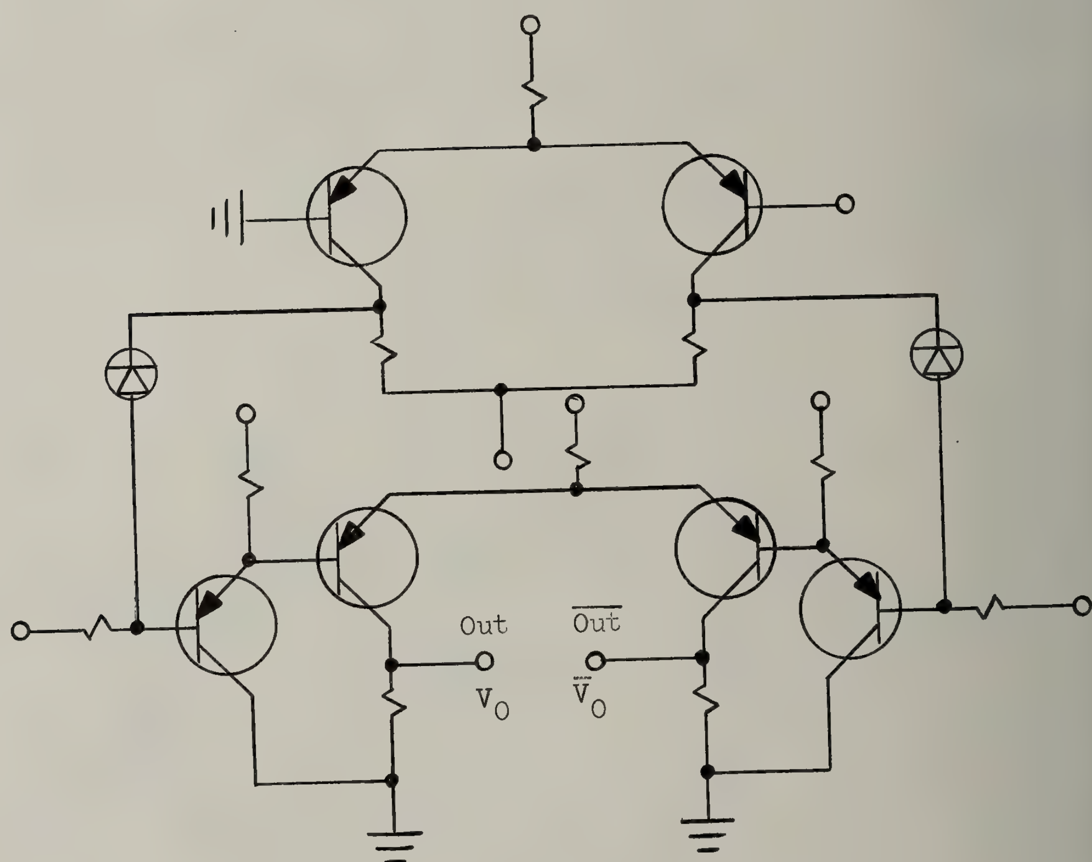


Figure 9

Difference Amplifier with Emitter-Follower

Measurement of the setting time of a flipflop was done using the circuit of Figure 10.

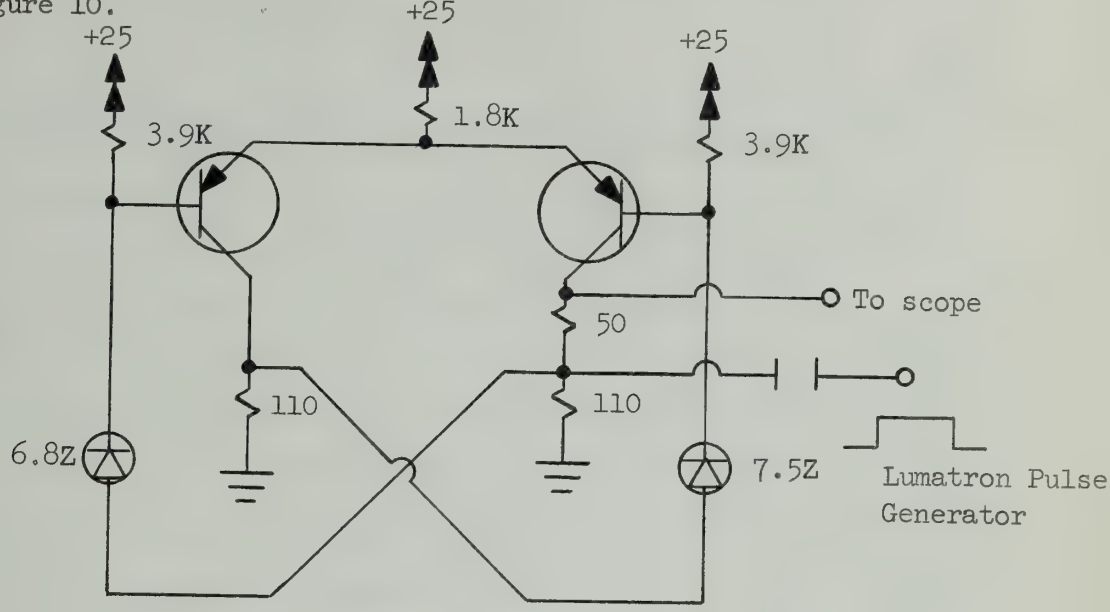


Figure 10

Flipflop Test Circuit

The waveform seen on the Lumatron scope is shown in Figure 11. The dotted line indicates the input pulse itself. The total time to set the flipflop by the Lumatron pulse generator (low impedance output) is of the order of 2.5 mμs.

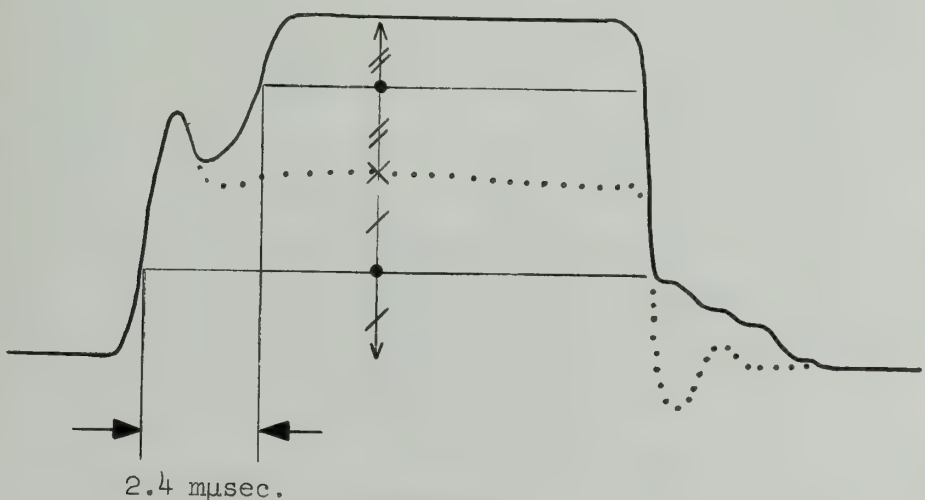


Figure 11

Flipflop Waveform

PART III

MATHEMATICAL METHODS

1. An Approximate Stress Energy Tensor For Gravitational Fields (Supported in part by the National Science Foundation under Grant G9503.)

A paper with this title has been submitted for publication in a technical journal. The abstract of the paper is as follows:

"An invariant formulation in Minkowski space-time of an approximation to the Einstein theory of gravitation is given. In this formulation a tensor is introduced which may be interpreted as the approximate stress energy tensor of the gravitational field. Conservation laws involving this tensor and the material stress energy tensor are formulated. The behavior of these tensors under "gauge transformations" of the weak gravitational fields is discussed. The classical limit of the conservation of energy equation is studied and the results are compared to some observations of H. Bondi on a possible analogue of the Poynting vector for a gravitational field."

(A. H. Taub)

2. Monte Carlo Methods In Quantum Statistics (Supported in part by the Office of Naval Research Under Contract Nonr-1834(27).)

The evaluation of the partition function for a quantum mechanical harmonic oscillator using the Monte Carlo path integral technique, mentioned in preceding reports, has been examined. In the two formulations that were considered, it was found that the variance of the Monte Carlo ensembles becomes infinite at a certain temperature; the location of this infinity is different for the two formulations. Although it has not been proven, it is certain that this infinity is a property of the method and that it has no physical significance. It does not appear that this infinity will cause any significant computational difficulties because it is possible to easily move it by appropriate formulation of the problem; there may be a way to entirely remove this infinity, or at least to take it off of the real axis, but this has not yet been found.

(L. D. Fosdick)

PART IV

DATA REDUCTION METHODS

(Supported in part by the National Science Foundation Under Grant G9503)

AUTOMATIC REDUCTION OF DATA FROM BUBBLE CHAMBER PHOTOGRAPHS

Attempts to characterize local patterns within bubble chamber photographs by pair counts in small rectangular domains (8-20 cell lengths) has been continued and extended. Multivariant analysis of the first production run is now in progress. In particular, the domain scoring routine has been extended to generate its own data tape in the following sense--randomly generated rectangular domains, random both with regard to size and position, on digitized bubble chamber photographs can now be picked up and examined by the scoring routine. This experiment is to see whether, of some 400 to 1,000 randomly selected domains, those domains which are characterized by having strong factor scores with respect to only one factor, that is, "simple" factor explanation, also have a simple human interpretation, i.e., do they correspond to clean segments of beam tracks, electron spirals, interaction vertices, etc.

Data tapes of human selectioned sequences of domains to be scored and results factor analyzed are being prepared. The human observer pre-sorts the domains into simple categories, beam track spirals, etc.

A program to generate by Monte Carlo methods, rectangular domains (up to 40 x 40 cells), subject to constrained pair counts has been completed. It has been experimentally verified and, more recently, theoretically verified that many simple patterns (parallel lines, rectangles, certain simple sets of rectangles, diagonal lines, etc.) have unique pair counts, that is, uniquely distinguishable up to a translation. The above program is being used to empirically suggest additional mathematical results.

The digital tracking routine has been applied to 108 tracks (of rather low quality, in particular, more than 50 per cent gap) and the results are now being analyzed by multivariant analysis. Systematic program biases have showed up. At present, the tracking routine tracks approximately 30 per cent of the human track length (given one initiating point per track).

(K. Dickman, K. Hillstrom, M. Kuchnir,
B. McCormick, J. Snyder)

PART V
ILLIAC USE AND OPERATION

New Illiac Codes

During the month of March, no new routines were added to the Illiac Library.

Illiac Usage

During the month of March, specifications were presented for 27 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 1888. Numbers followed by T are for theses.

1888 Digital Computer Laboratory. Linear Graph Structure. A number of different problems in linear graph theory will be investigated. Most of these involve the computation of characteristic functions for various types of graphs. In the first instance a function of the form $F(n,a,\varphi,b)$ will be computed where n is an integer, a in $\{0, 1/2, 1\}$, φ in $\{0, 1\}$, b in $\{0, 1/2, 1\}$. This function is given by the recursive formulas

$$F(n,a,1,b) = \max_{n_1+n_2+1=n} \min_{x=0,1} \left(F(n_1,a,x,1) + F(n_2,1,1-x,b)\right)$$

and $$F(n,a,\varphi,b) = F(n,b,\varphi,a) = -F(n,1-b,1-\varphi,1-a).$$

1889 Chemistry. Isotopic Exchange Reactions. This is a continuation of problem 1183T. In this phase of the work, reaction probabilities and vibration transitions are to be calculated for reactions of the type $H + H_2 \rightarrow H_2 + H$ in which the isotopic mass of any or all of the hydrogen atoms may be substituted by that of deuterium or tritium. The bulk of the time in the program is used to calculate values of the interatomic forces by interpolating within a stored matrix of potential energy values for various relative positions of the atoms. The program is essentially the one used in problem 1183T.

1890 Psychology. Specificity of Value Achievement Orientation to Manic-Depressives. This problem is an outgrowth of a research program which was designed to test two clinically derived, partially conflicting psychodynamic formulations regarding certain salient aspects of the character structure of manic-depressives. The clinical formulations were redefined in terms of conceptually relevant operational measures upon which the performance of manic-depressives and normals was compared. The nature of the measures permitted a determination of whether the manic-depressives as compared with normals were more value-achievement oriented as Cohen, et al.'s position would indicate, or more need-achievement as Ariete has suggested.

The present study is an attempt to determine whether the value achievement characteristics which the original study found to characterize manic-depressives is specific to that psychodiagnostic entity or simply characteristic of psycho-pathological groups per se. Therefore, this study compares the scores of schizophrenics and neurotic-depressives with those of manic-depressives and normals on three attitude measures of, or related to value achievement.

1891T Sociology. A Comparison of Methods of Crime Prediction. Twenty pre-prison variables such as age, age at first arrest, highest grade completed, number of previous commitments, etc. have been obtained for 969 prison inmates. The research problem is to determine the best weights for these variables in order to predict recidivism as measured by three criteria, which are: most serious post-release criminal record, time from release to first new criminal record entry, and time from release to offense.

An attempt will also be made to understand the relationship between predictors and between predictors and criteria by the use of a factor analysis and to see if any stability is gained in prediction by using factor scores rather than variables. The test of any prediction table is its ability to predict a new sample, i. e., validation. This is to be done by using an N of 749 to get the β weights and then validating these weights on a new sample with an N of 220.

1892 Theoretical and Applied Mechanics. Natural Frequencies for Beams. Finite difference techniques will not lead to a normal eigenvalue problem with symmetric matrices when one is seeking the natural frequencies of an unsupported beam. However, by adding and subtracting the same function the problem can be changed to a beam on a continuous foundation. The eigenfunctions are identical and the frequencies differ by a constant.

The dependence of the frequencies on the choice of spring constant and the size of the difference mesh will be investigated. If the results are good this will lead to a unified method for finding the natural frequencies under very general conditions.

Code M-20 is used to find the eigenvalues and a short routine (in floating point) computes and scales the coefficients and punches them for direct input to M-20.

1893T Agricultural Economics. Effects of Lender Policy on Farm Organization. The problem is to determine optimal organizational response of a heavily indebted farm business to different combinations of lending policies which form a set of restraints on behavior. The problem can be formulated as maximizing a linear function, profits, subject to linear constraints imposed by lender decisions and farm production alternatives. Lender policy variation is studied by varying several parameters which represent forms of financial restraint on the business.

1894 Physics. Magnetic Lens Simulator. A system of focusing, defocusing and bending magnets is to be designed for guiding a 50 mev. beam of protons from the Linac to the Synchrotron injector at the Argonne Zero-Gradient Synchrotron. The beam from the Linac can be specified by two two-component vectors:

$$\begin{pmatrix} x_0 = A \sin \theta \\ \dfrac{dx}{dz_0} = B \sin (\theta + \alpha) \end{pmatrix}$$

and

$$\begin{pmatrix} y_0 = C \sin \theta \\ \dfrac{dy}{dz_0} = D \sin (\theta + \beta) \end{pmatrix}$$

The open sections between magnets have lengths S_n and operate on the two above vectors like the matrix $\begin{pmatrix} 1 & S_n \\ 0 & 1 \end{pmatrix}$. The focusing sections operate on the vectors as the matrix

$$\begin{pmatrix} \cos w_n \ell_n & \frac{1}{w_n} \sin w_n \ell_n \\ w_n \sin w_n \ell_n & \cos w_n \ell_n \end{pmatrix}$$

The defocusing sections operate on the vectors as the matrix

$$\begin{pmatrix} \cosh w_n \ell_n & \frac{1}{w_n} \sinh w_n \ell_n \\ w_n \sinh w_n \ell_n & \cosh w_n \ell_n \end{pmatrix}$$

The bending magnets act on the x-vectors as the matrices

$$\begin{pmatrix} 1 & 0 \\ \frac{y_2}{\rho} & 1 \end{pmatrix} \begin{pmatrix} \cos\gamma & \rho \sin\gamma \\ \frac{-1}{\rho} \sin\gamma & \cos\gamma \end{pmatrix} \begin{pmatrix} 1 & 0 \\ \frac{y_1}{\rho} & 1 \end{pmatrix}$$

and on the y-vectors as the matrices

$$\begin{pmatrix} 1 & 0 \\ \frac{-y_2}{\rho} & 1 \end{pmatrix} \begin{pmatrix} 1 & \rho\gamma \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ \frac{-y_1}{\rho} & 1 \end{pmatrix}$$

If the matrices above are designated by M_n, then the state of the beam after passing through the system can be described by vectors

$$\begin{pmatrix} x \\ \frac{dx}{dz} \end{pmatrix} = \prod_{n=1}^{N} M_{nx} \begin{pmatrix} x_0 \\ \frac{dx}{dz_0} \end{pmatrix}$$

$$\begin{pmatrix} y \\ \frac{dy}{dz} \end{pmatrix} = \prod_{n=1}^{N} M_{ny} \begin{pmatrix} y_0 \\ \frac{dy}{dz_0} \end{pmatrix}$$

where the M_{nx} and M_{ny} are the appropriate set of matrices to represent the effect of the magnets and open sections.

The parameters s_n, w_n, ℓ_n, y_1, ρ, γ and the momentum of the protons, as well as a description of the configuration of the magnets is to be read by Illiac from a set of switches. A graph of the beam profile as it passes through the system and phase diagrams of the x and y vectors at

a selected point along the system are to be displayed via a storage tube and read out onto a TV display. The user will then adjust parameters while watching the resultant graph until he gets the type of beam guiding desired.

This problem was studied for programming as a 12-parameter optimization problem on the IBM 704 and it was concluded that it would take 63 years to obtain a solution. The electronics division of Argonne is building a $50,000 analog computer to attempt a restricted solution to the problem. This program is an attempt to make Illiac behave like an analog computer of greater capacity for a more complete solution to the problem.

1895 Psychology. Structure of the 16PF and ICL. There are two purposes of the present research. One is to fill in a gap in a series of correlational studies involving well-known psychodiagnostic tests such as the Rorschach, Minnesota Multiphasic Personality Inventory, Cattell 16PF, and Interpersonal Checklist. Comparisons of the structures of the last two named tests based on the same sample of persons are needed to complete the picture of the correspondences and differences among the kinds of information supplied by the various tests.

It is proposed to intercorrelate the variables of the ICL and the 16PF, Forms A and B, then to obtain the principal components, and finally to rotate to simple structure by means of the Varimax principle. This procedure is to be followed for the separate and the combined correlation matrices, after which matching of factors can be carried out.

Illiac will be used to perform the intercorrelation of test scores, to obtain the principle components, and to rotate to simple structure.

The second purpose is to obtain the intercorrelations among the 134 items of the ICL (as opposed to the score intercorrelations referred to above). These item intercorrelations are crucial in evaluating the development of the ICL itself. In the initial development of the ICL, approximations to the intercorrelations were used because no digital computers were available. Now, the complete 134 by 134 matrix of intercorrelations can be obtained with relative ease by the Illiac. A further difference between the initial study and the proposed study is that a student sample will be used in the proposed study, whereas a sample of outpatients was used initially.

It is proposed to obtain intercorrelations among the items, factor these intercorrelations, and compare the obtained factor loadings with the scoring weights now used in the ICL. Presumably, certain items will be replaced or modified on the basis of this comparison, so that an improved version of the ICL should result from the present study.

1896 Astronomy. Integration of Isothermal Cores for Stars. This is a problem in stellar structure for the calculation of isothermal stellar configurations. The density is high enough for the equation of state of a partially degenerate gas to apply to the electron gas.

The mathematical problem consists in the solution of the following system of two simultaneous ordinary differential equations, with different boundary conditions:

$$\frac{d\psi}{d\xi} = \frac{\varphi}{(1+\delta)\xi^2}$$

$$\frac{d\varphi}{d\xi} = -F_{1/2}(\psi)\xi^2$$

where $$\delta = c\,\frac{1}{F_{1/2}(\psi)}\;\frac{dF_{1/2}(\psi)}{d\psi}\text{, c is a constant.}$$

$F_{1/2}(\psi)$ and $\frac{dF_{1/2}(\psi)}{d\psi}$ are known and can be expressed in analytical form as a function of ψ. The library routine F1 is used for the integration.

1897T Physics. K^- Meson Multiple Scattering. The optical potential U, for K^- mesons in nuclei, may be written formally:

$$U(K) = \sum_i t_i + \ldots \tag{1}$$

$$t_i = t_F \frac{1}{1 - \left[\frac{\alpha}{a-U} - \frac{1}{a_F}\right] t_F} \tag{2}$$

where t_F is the free scattering matrix, α is a projection operator, $\frac{\alpha}{a-U}$ is the Green's function for K^- - Nucleon Scattering inside the nucleus, $\frac{1}{a_F}$ the free Green's function for K^- - Nucleon Scattering from free particles. Using infinite nuclear matter, the Green's functions become reasonable, and zero range t_F makes the above operator relation (2) a numerical expression:

$$t_i = -\frac{4\pi}{2\mu} \frac{A}{1 - ik_0A + A\frac{4\pi}{(2\pi)^3}\left[\int_{P_F}^{\infty} \frac{d\bar{K}}{k_0^2 - K^2 - 2\mu U(K) - 2\mu V(P)} - \int_0^{\infty} \frac{d\bar{K}}{k_0^2 - K^2}\right]} \quad (3)$$

Mathematically, the problem is one of a double integral over the Fermi Sea in (1) and a double integral in the denominator of (3), plus a self consistency (since U(K) appears in (3)) which takes 2-4 overall iterations.

1898 Electrical Engineering. Extrapolation of Band Limited Functions. Given a function P(x) on the finite interval $0 \leq x \leq L$, let P(x) be approximated by the method of least squares with the function

$$P_N(x) = \sum_{h=0}^{n-1} P_k \left[\frac{\sin(\beta x - h\pi)}{\beta x - h\pi} \pm \frac{\sin(\beta x + h\pi)}{\beta x + h\pi}\right]$$

(+ sign if P(x) is an even function)

(- sign if P(x) is an odd function)

This leads to N simultaneous linear equations which in matrix form are given by

$$\begin{bmatrix} A_{00} & A_{01} & A_{02} \\ A_{10} & A_{11} & \\ & & \\ & & \end{bmatrix} \begin{bmatrix} P_0 \\ P_1 \\ \cdot \\ \cdot \\ \cdot \end{bmatrix} = \begin{bmatrix} B_0 \\ B_1 \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$$

where

$$A_{jh} = \int_0^L \left[\frac{\sin(\beta x - h\pi)}{\beta x - h\pi} \pm \frac{\sin(\beta x + h\pi)}{\beta x + h\pi}\right]\left[\frac{\sin(\beta x - j\pi)}{\beta x - j\pi} \pm \frac{\sin(\beta x + j\pi)}{\beta x + j\pi}\right] dx$$

$$B_\ell = \int_0^L P(x)\left[\frac{\sin(\beta x - \ell\pi)}{\beta x - \ell\pi} \pm \frac{\sin(\beta x + \ell\pi)}{\beta x + \ell\pi}\right] dx$$

L will take on several values.

N will vary up to about 100.

P(x) will be varied also.

1899 Agronomy. Morphological Study of Small Grains. The effect of fertilizer treatments, varieties, locations and years will be studied using analysis of variance on wheat and oats relative to the following characters: number of internodes, length of internodes, head length, total height, per cent of total height the different nodes represent.

1900 Digital Computer Laboratory. Studies of Automation of Bubble Chamber Data Reduction. Digitalized photographs of high energy events in a hydrogen bubble chamber have been checked for consistency and displayed as described under specification 1740. These photographs are to be subjected to extensive processing to extract statistical information in an attempt to discover which parameters and which quantities characterize the essential features of such a picture. These studies will embrace several different procedures.

The ability to automatically follow a particle track in the presence of gaps and background noise is to be studied for a large class of tracks of differing quality.

Local bit patterns are to be analyzed in an attempt to determine criteria which will make possible the efficient discovery of good points at which to initiate tracking.

1901T Economics. The Composition of Consumer Savings. This thesis is a study of the composition of consumer's savings portfolios. To date, practically no information is available on this topic. Yet the structure of consumer savings and changes in this structure exert important influences on financial institutions, general financial conditions, and on the aggregate economy.

The major objectives of the thesis are: (1) to determine the relationships between different types of assets, both in terms of ownership and amounts held in the assets; (2) to determine the influence of various consumer characteristics on the structure of the total savings portfolio.

The Illiac is needed to help determine many of these relationships. Using library program K-14 with the log transformations, the degree of relation between the amounts held in the assets will be studied. K-14 will also be used to study the relation between the structure of the total portfolio and approximately 20 independent variables.

1902 Psychology. Study of Conflict. Data collected over 16 conflicts using 23 devices and 86 children are to be analyzed. When components for devices are understood, then the appropriate devices will each be added together. A factor analysis of <u>content</u> will then be carried out on the basis of each of the components, and the structure of conflict will be described on the different motivational levels.

1903 Psychology. Item Analysis of the Industrial Analysis Test. A number of objective motivation measurement items have been developed and given to subjects. The computer is to be used to ascertain the structure of vocational interest and to determine which of the items best measure these dimensions.

1904 Education. The Interrelation of Achievement and Personality for Elementary Education Students. Scores for 273 students in Elementary Education, 209 women and 64 men, have been obtained. The scores include 11 achievement test scores in Science, Social Studies, Reading, and English Mechanics as well as three scores on the School and College Ability Test and five scores on the Minnesota Multiphasic Personality Test, the high school rank and the grade point average of each student.

The purpose of the study is to investigate the type of student who enters Elementary Education and the applicability of this battery of tests to this select group. This information may be obtained by an investigation of the interrelations of these scores and the possible factors underlying the responses for these students. It is also thought that men and women students in this field may differ in these respects.

Illiac will be used to give the intercorrelations of these scores, the means and standard deviations for each group; and, by factor analysis, information about the interrelatedness of the various tests. With such information more accurate interpretations of each student's scores will be possible.

1905 Coordinated Science Laboratory. F. N. Field Emission Calculation. It has been shown that field emission through the field reduced potential barrier of a metal surface departs from the Fowler-Nordheim relationship at high field strengths. This deviation may be explained by an increase in the effective work function of the surface due to the surface charge density which supports the field.

The current density as a function the field intensity, the work function, and the surface charge density will be calculated and compared to the experimental data.

1906 Physics. Wigner-Seitz Calculation. The cohesive energy of a solid is calculated by the Wigner-Seitz method using a potential in the form of a short table. The appropriate wave equation is integrated by the Runge-Kutta method on the digital computer. The values of the potential intermediate to the tabulated values are obtained by successive linear interpolation.

1907T Civil Engineering. Lateral Stability of Beams. The problem is to determine the lateral stability of beams with variable sections. The problem reduces to finding eigen values λ of a matrix of finite order. The elements of the matrix are functions of the eigen value λ. Then solutions of linear differential equations with variable coefficients will be obtained. The coefficients are polynomials in the independent variable.

1908 Psychology. Analysis of Motivation Tests. The purpose of the analysis is two-fold, viz., to resolve a set of measures of human motivation into a smaller number which, it is believed, will be scientifically more meaningful; and to estimate the probable usefulness of certain of these measures for general prediction problems in vocational guidance and selection.

The analysis will involve the combination of measures using matrix multiplication, correlation of the resulting compounds, factor analysis and rotation to determine a smaller but scientifically meaningful basis for the vector space, and the multiple correlation of selected variables with various practical and theoretical criteria.

1909 Physics. Signer-Seitz Calculation. The problem is to solve the differential equation

$$y'' + \frac{2}{x} y' + (10 \frac{A(x)}{x} - \lambda) y = 0$$

for values of x between 0 and 4.5, where y is the radial wave function, $(-10A(x)/x)$ is the potential of the lithium ion, and λ is a variable parameter associated with the energy.

Furthermore, it is desired to obtain those values of $x = x_0$ for which $y' = 0$, again for various values of λ. The x_0 can be used to determine the lattice parameter of L_1 metal and to give an estimate of the cohesive energy.

1910 Physics. Numerical Integration of Wave Equation. This program is to solve the Schrodinger wave equation for a tabulated potential by numerical integration. The program starts with a value of the energy for which the wave function has a minimum and a maximum and by iteration determines the energy at which the maximum and minimum converge to a single minimum. For each value of the energy the program prints out the energy and the distance coordinates of the maximum and the minimum. Tests are included so that the program stops after calculating the energy to three decimal places or after determining that a maximum or minimum occurred at the same coordinate as was previously calculated.

In the iteration process, the new energy values calculated are approximately half-way between the desired value and the one previously used. It should therefore take no more than nine or ten trials to calculate the energy within the accuracy desired.

1911T Agricultural Engineering. Jet Penetration. By means of conformal mapping, the flow pattern is determined for a jet penetrating into a counter flow. The streamlines in the velocity plane are to be determined by plotting the values of the velocity components, u and v, which correspond to an assigned value of the stream function, ψ, as given by an expression $\psi = \psi(u,v)$. To determine the flow in the physical plane, solutions to the equations $x = x(u,v)$ and $y = y(u,v)$ are to be found and plotted for values of u and v which were determined from $\psi = \psi(u,v)$. The Illiac is to be used to compute the numerical value of the equations $\psi = \psi(u,v)$, $x = x(u,v)$, and $y = y(u,v)$ for approximately 1200 values of u and v.

1912T Agronomy. Effect of Row Spacing, Planting Rate, and Fertilizer Treatment on Grain Sorghum. This research pertains to three variables, which are: row width, planting rate, and fertilizer treatment. There were four different row widths, four different planting rate groups, and two different fertilizer levels. There were 128 plots or treatments in total.

On the individual plots, 20 different characteristics were recorded. The data will be reduced by the method of least squares.

The purpose of this experiment is to determine which row width, planting rate, and fertilizer treatment may be be most applicable to farming in Illinois.

1913 Institute of Communications Research. Cross-Cultural Study of Synesthesia. The purpose of the research is to test the cross-cultural generality of visual-verbal synesthesic tendencies. One group of subjects is American, the other is Japanese.

The instrument used for the analysis of data was a Semantic Differential with 60 concepts (16 color, 14 word, and 14 figure stimuli) and 35 seven-point scales representing the evaluation, potency and activity dimensions.

In the analyses, the data from each group will be factor analyzed by using scale-by-scale intercorrelations and concept-by-concept intercorrelations. The scale-by-scale factor analysis will be done by means of Illiac routines, K8 for intercorrelations, KSL 1.20 for centroid factor analysis with fixed communalities, and KSL 1.80 for varimax rotation. The concept-by-concept factor analysis will follow the same procedure after the original data is transposed by the KSL 5.30 routine. Inputs to K8 program will be code checked by KSL 5.90 routine. In the final analysis, the factor structure of each group will be compared by means of intercorrelations between rotated factor scores for American and Japanese groups. K8 program will be used in this analysis.

1914 Psychology. Personality Test Development. The basic problem is to develop a test for a given set of personality factors as determined by a recent factor analytic study of the personality. The prior solution, although adequate for exploratory purposes, will be checked and further improved, if possible, by rotation. After this, the factor scores will be estimated by inverting the original correlation matrix, post multiplying by the factor structure, raw scores, etc. The test will be developed by correlating a series of items also given to the same subjects with the factor estimates, and selecting the best items to use, in further research, as an estimate of the subjects' actual factor scores.

Table I shows the distribution of Illiac machine time for the month of March.

TABLE I

	Hrs:Min	
Scheduled Maintenance	69:13	
Unscheduled Maintenance	18:03	
Drum Engineering	8:14	
Leapfrog	4:35	
Library Development	6:28	
Classes	20:52	
Demonstrations	23:14	
		150:39

Use by Departments

Agricultural Economics	10:55
Agricultural Engineering	:30
Agronomy (0015-15-306)	:43
Agronomy	4:52
Animal Science	:02
Astronomy (NSF-G-14834)	:49
Bureau of Community Planning (84-16-383)	1:19
Bureau of Educational Research	2:15
Chemistry (NSFG 7336)	3:44
Chemistry	33:28
Civil Engineering (AASHO ROAD TEST)	:53
Civil Engineering (NSF-G 6572)	1:37
Civil Engineering (NONR 1834(03))	:09
Civil Engineering (IHR-46)	:11
Civil Engineering	74:49
College of Medicine (NIMH-USPH-M-637)	4:40
Coordinated Science Lab. (DA-36-039-SC56695)	56:55
Digital Computer Laboratory (NSF GRANT 9503)	14:19
Digital Computer Laboratory	1:58
Economics (NSFG 7056)	6:43
Economics	:07
Education	:04
Electrical Engineering (NONR 1834(22))	:04
Electrical Engineering (NASA-NSFG 24-59)	6:59
Electrical Engineering (NSFG 7421)	1:07
Electrical Engineering (IOWA GRANT 1955)	:31
Electrical Engineering (NONR 1834(02))	:03
Electrical Engineering (AF 7043)	:19
Electrical Engineering	9:54
Finance (IHR-71)	2:10
Geological Survey	:08
Geology	:07

Institute of Communications Res. (44-28-20-378)	12:48
Institute of Communications Res. (USPHM-3941)	1:36
Institute of Communications Research	:10
Institute of Labor and Industrial Relations	2:53
Inst. for Res. on Excep. Children (44-20-70-312)	:39
Inst. for Res. on Excep. Chil. (AE AND WSAE 8204)	2:58
Inst. for Res. on Excep. Chil. (USPH NIHM-3207)	:06
Marketing	:10
Mathematics	7:55
Mechanical Engineering (DA-11-022-ORD 1980)	:35
Mechanical Engineering (NSG-13-59)	:51
Mechanical Engineering	8:24
Mining and Metallurgical Engineering (CML 51F)	1:05
Music	2:50
Physical Education	:46
Physics (ORD 1001)	:02
Physics (NONR 1834(05)A)	2:02
Physics	28:53
Provost Office	:13
Psychology (MD 2060)	:32
Psychology (M1774)	:55
Psychology (AF 49(638)371)	5:44
Psychology (SAE 8383)	2:38
Psychology (1715)	2:52
Psychology (ONR-46-32-66-362)	:45
Psychology	53:06
Sociology	:48
State Water Survey	8:03
Theoretical and Applied Mechanics (AF(616)6643)	:55
Theoretical and Applied Mech. (DA-11-070-508 ORD)	3:30
Theoretical and Applied Mechanics	7:23
Veterinary Physiology	1:15
Zoology	:52
Williams College	3:58
	410:46
	561:25

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This

is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Arithmetic	1
Control	1
Reader	1
Power Failures	1
Drum Failures	9
Unknown	5
Total	18

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/1/61	20:04	2:26	1:30	1	(1) Drum failure.	:00	:13	0
3/2/61	17:16	:25	6:19	1*	(1) Drum failure.	:00	:20	0
3/3/61	21:35	:02	2:23	1	(1) Drum failure.	:00	:00	0
3/6/61	20:23	:00	3:37	0		:00	:06	0
3/7/61	19:58	:04	3:58	1	(1) Unknown.	:00	:01	0
3/8/61	20:02	:32	3:26	1	(1) Drum failure.	:00	:00	0
3/9/61	20:56	:27	2:37	2	(1) Drum failure. (2) Drum failure.	:00	:24	0
3/10/61	20:58	:00	3:02	0		:00	:00	0
3/13/61	21:50	:00	2:10	0		:00	:00	0
3/14/61	20:46	:00	3:14	0		:00	:05	0
3/15/61	20:34	:00	3:26	0		:00	:31	0
3/16/61	20:18	:00	3:42	0		:00	:45	0
3/17/61	21:50	:00	2:10	0		:00	:00	0
3/20/61	20:39	:12	3:09	1	(1) Unknown.	:00	:04	0
3/21/61	20:41	1:19	2:00	2	(1) Drum failure. (2) Illiac Control-Bad Tubes.	:00	:21	0
3/22/61	18:22	3:30	2:08	2	(1) Arithmetic failure. (2) Reader "F" erred.	:00	:11	0
3/23/61	18:35	1:40	3:45	3	(1) Drum failure. (2) Unknown. (3) Unknown.	:00	:00	0
3/24/61	12:48	9:14	1:58	2	(1) Unknown. (2) Drum failure.	:00	:00	0
3/27/61	20:48	1:03	2:09	1	(1) + 100 v power supply failure.	:00	:16	0
3/28/61	22:30	:00	1:30	0		:00	:05	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/29/61	21:30	:00	2:30	0		:00	:37	0
3/30/61	21:22	:00	2:38	0		:00	:04	0
3/31/61	22:16	:00	1:44	0		:00	:00	0
					*-3:47 - used by Physical Plant on air conditioning for drum.			
TOTALS	466:01	20:54	65:05	18		:00	4:03	0

PART VI

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New International Business Machines 650 Codes

During the month of March, one new 650 routine was added to the International Business Machines 650 Library.

K8' - 71' Analysis of Variance of Latin Square Designs with Single Degree of Freedom Analysis. This program computes and prints out the treatment means, analysis of variance table, and single degree of freedom analysis for data obtained from Latin Square design experiments. The single degree of freedom analysis provides for factorial analysis of 1, 2, or 3 factors.
All data and coefficients are read in as fixed point numbers and converted to floating point for computations. Output is printed on the 407 in fixed point form.

(S. G. Carmer, Agronomy)

International Business Machines 650 Usage

During the month of March, specifications were presented for 17 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 217'. Numbers followed by T are for theses.

217' Chemistry. Nuclear Magnetic Resonance. The problem is to analyze nuclear magnetic resonance data for several aromatic halogen compounds. Fitting a theoretically derived curve (involving exponentials) to the data is expected to yield information on rotational energy barriers. Since the form of the curve is not amenable to standard least squares treatment, a successive approximations procedure will be used.

218' Navy Pier. Nelson-Denny Study. This analysis consists of intercorrelations among Nelson-Denny Reading Test scores and freshman guidance examination scores which are presently used at Navy Pier. The need for this analysis is to evaluate the Nelson-Denny Reading Test in terms of standard tests commonly used in college counseling programs.

219' Navy Pier. College Entrance Examination Board Re-Test Study. This analysis is needed to establish test-retest reliability coefficients of the College Entrance Examination Board Scholastic Aptitude Tests, and relation of College Entrance Examination Board to American College Tests test scores.

Test results used in this study were taken from entering freshmen at the Navy Pier campus of the University of Illinois.

220' Civil Engineering. Optimum Prestressing Steel Location in a Two Span Continuous Beam. The problem concerns a two span continuous prestressed concrete beam with equal span lengths, uniform cross section, uniform live load on both spans, and variable steel location of second degree parabolic form.

Input data required is: variables used in proportioning the cross section, multiple design criteria, the cross section area and depth, unit weight of concrete, uniform live load, span length, parameters defining the initial steel location, a factor defining steel cover requirements, the number of sections into which the span is to be divided, and the maximum number of iterations the program will be allowed to perform.

The program is to compute the steel location parameters which will satisfy all multiple design criteria at a given number of equi-spaced points on the span for a given live to dead load ratio, and to determine the relative effect of change of the various parameters.

The general method of solution is iterative with modification of parameters based on simplified linear approximations of gradients obtained from partial differentiation. The span is divided into ten or more sections and the multiple design criteria checked at each section. If the criteria are not satisfied, one of the steel location parameters is modified and another trial is made. If this trial is unsatisfactory, another steel location

parameter is modified and another trial is made. The steel location parameters are modified in predetermined rotation. This iterative process is continued until all multiple design criteria are satisfied or a limiting number of iterations is performed.

221' Education. Critical Thinking Project. This research problem is one of a series of studies which is being conducted in order to help evaluate specially designed materials and methods used in teaching "critical thinking".

In this study, a series of correlations and analyses of covariance is being used in order to determine whether the use of the special educational materials and methods resulted in increased "critical thinking" ability. Scores obtained on two different sets of pre- and post- tests taken by both the experimental and the control students are used in the correlations and in the analysis of covariance. Both the experimental and the control students have been grouped according to subject matter area and grade level.

222' Dairy Science. Reliability of Desoxy Riobo Nucleic Acid Measures. Means, standard deviations and correlations involving several micro measurements of Bovine sperm together with microspectrophotometric measures of these same sperms are needed to obtain estimates of reliability in the development of measurements of Desoxy Riobo Nucleic Acid in individual sperm cells.

223'T Chemistry. Energy Levels of Nickel Dimethylglyoxime. The problem is to find the energy levels as a function of the molecular parameters of nickel dimethylglyoxime. The observed spectral lines shift in energy as the applied pressure is increased. Using crystal field theory, a model has been devised which will predict the shift. It is necessary to use the 650 to cover a wide range of the parameters in a reasonably short time.

The energies are to be calculated from simple algebraic forms such as the following:

$$E^b = \not{c}\left[\frac{1}{14}\left(\frac{2a^2 - b^2}{(a^2 + b^2)^{5/2}}\right) + \frac{3}{14}\left(\frac{b^2}{(a^2 + b^2)^{5/2}}\right) \sin 2\alpha + b^2 s \left\{ - \frac{1}{14}\left(\frac{8a^4 - 24a^2b^2 + 3b^4}{3(a^2 + b^2)^{9/2}}\right)\right.\right.$$

$$\left.\left. + \frac{5}{42}\left(\frac{6a^2b^2 - b^4}{(a^2 + b^2)^{9/2}}\right) \sin 2\alpha \right]$$

where $\quad$ a, x, y, and z represent 4 distances

α represents an angle

ϕ represents a charge

s is a predetermined constant.

224' Mining and Metallurgical Engineering. Electric Analog Computation. The potentials of nodes in a resistance network are to be computed. With given resistors and boundary conditions, the potentials at 1, 2, 3, ... n, a matrix involving eight such nodes are to be found. The problem is resolved into computing the solution of 12 simultaneous linear equations.

Using an alternating explicit and implicit technique, values (solutions to linear equations) such that the network is satisfied are to be found. Ohm's law is applied at each node; a system of linear equations is formed; the first approximations are computed; then using the first approximation for potentials, a new set of linear equations are derived, the solutions of which form the second approximation, etc. When the desired accuracy is acquired, i. e., when the n^{th} approximation differs from the $n + 1^{th}$ approximation by less than .001, the results will be printed.

225' Civil Engineering. Vehicular Speed Analysis. This problem is to calculate various average and percentile speeds, speed differentials and summary analyses for samples of vehicle travel on Illinois highways. Also, the functional relationship between standard deviation of vehicular speeds and average annual daily traffic will be established by linear regression analysis.

The data consists of approximately 300 samples, with 200 to 600 observations per sample. The individual observations have been stratified into groups according to vehicle type.

226' Physics. Bubble Chamber Range Angle. The program will analyze events occurring in a bubble chamber with no magnetic field, using range and angle of tracks.

The first chore is to reconstruct the coordinates in space at the beginning and ending of tracks, from the measured coordinates in two (sometimes three) camera views. This is a simple geometrical problem, only

slightly obscured by refraction, defects in the optical system, and the need to establish the origin and orientation of the coordinate system on the film, using fiducials. The reconstruction part of the program, as well as the decoding and storing of the input, is common to all event types.

The second chore is to use range and angle information to calculate interesting parameters for the event, e. g., energy, and center-of-mass angle. In some cases ambiguities will have to be resolved. In the kinematic analysis many of the steps are common to all or at least many types of events. For this reason, the program is designed so that most functions are carried out in closed subroutines. Those parts of the program dealing with specific event types will have to carry out only administrative and logical decisions.

The input data from the measuring machine will be transcribed from tape to cards, as a continuous eight word per card record, i. e., without reference to beginning or ending of cards.

The output will consist of a printed summary and of a magnetic tape record. The tape record may be used as input for subsequent analysis, e. g., grouping of events by energy or angle.

227' State Water Survey. Positive Area Stability Analysis. This program will compute the positive area between the actual lapse rate of an upper air sounding and a moist adiabatic lapse rate generated by an unstable parcel of air as it rises through the atmosphere.

The parcel of air originally rises at the dry adiabatic lapse rate which is determined by the solution of Poisson's Equation,

$$\theta = t \left(\frac{1000}{p}\right)^{R/C_p}$$

and the vapor pressure equation

$$e_s = 6.11 \times 10^{AT/B+T}.$$

After the parcel becomes saturated, it rises at a moist adiabatic lapse rate which can be approximated by the constant entropy equation,

$$E = C_p \ln T - R \ln (p-e_s) + \frac{wL}{T} .$$

The area generated between this curve and the actual lapse rate is then computed by summing the temperature differences at the various pressure levels using

$$A = \sum \frac{T_2 - T_1}{p} \Delta p$$

Θ = dry adiabatic lapse rate

T = temperature of air parcel at pressure p

R = .287

C_p = 1.003

w = mixing ratio in gms/gm

L = heat of vaporization.

228'T Civil Engineering. Statistical Analysis of Soil Sampling. This thesis subject is an engineering study of Humic-Gley soils in Illinois. These soils are regarded as trouble makers in highway engineering. One of the aims of this research is to determine the variability of the index properties of each soil type. The variability of the index properties can be estimated from test data of limited number of soil samples with the aid of simple statistics, such as: Mean, Standard Deviation, Coefficient of Variation, Standard Error of the Mean and Limit of Accuracy. This problem is programmed to calculate these statistics.

229' Civil Engineering. Operations Research. The applications of the computer to military engineering problems which can be adapted to linear programming will be studied. These will be general, typical problems encountered in everyday Corps of Engineer operations such as supply and logistics, construction operations, and transportation. The typical problems with solutions will be filed in a brochure which will serve as a ready reference to anyone encountering a type problem.

230' Statistical Service Unit. Tape Checking. This will be a recurring job to check and edit Statistical Service Unit magnetic tapes that have given machine errors as a result of tape drive or other damage. The program finds the defective spot on tape so it may be split into two usable shorter tapes.

231' Civil Engineering. Finite Difference Solution of Plates. The proposed program will assemble the coefficient matrix of the finite difference approximating equations for rectangular plates, solve these equations for the deflections at the finite number of node points within the plate, and then compute moments and shears at any node points desired.

232' Sociology. Characteristics of Married Students and Their Wives. The data of this study are based on two samples, one of 78 undergraduates and the other 40 wives of students. Questionnaires were administered to both groups to determine their academic status, social background, career aspirations, attitudes toward marriage, dating experience, expectations about campus life, social participation and other information which would distinguish the married student population from the unmarried. Some 50 items were collected for the male undergraduates and about 70 for the wives.

The International Business Machines 650 will be used to correlate the items within each sample to discover the patterns of trait which distinguish married and unmarried students from each other and to show the range of adjustment which wives of students make to the demands of the role of wife of student.

233' Business Office. Installment Accounts Receivable Year Ending Procedure. A program will be developed to adapt the 650 to prepare a year ending report on the Installment Accounts Receivable Problem 171'. The year ending report will include a merging of 15 reels of detail tapes which have been accumulated through the year, and zero balancing this entire file to the master tape used in problem 171'. Following this, the entire detail tape will be listed to be filed in the Bursar's Office.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of March.

TABLE I'

		Hrs:Min	
Scheduled Engineering		27:35	
Unscheduled Engineering		38:50	
Air Conditioning		:24	
Agronomy Library		:33	
Digital Computer Laboratory Library		4:51	
Classes		4:35	
CE 391	:12		
MATH 395	4:23		
Wasted		3:33	
			80:21

Use by Departments

Agricultural Economics		13:51		
Agronomy		16:30		
Animal Science		:17		
Astronomy		9:07		
Chemistry		14:41		
Civil Engineering		22:32		
Digital Computer Laboratory		4:31		
Electrical Engineering		:27		
Graduate College		3:20		
Horticulture		:21		
Mechanical Engineering		28:05		
Mining and Metallurgical Engineering		1:59		
Physics		4:39		
Small Homes Council		1:30		
Sociology		:20		
State Water Survey		6:31		
Statistical Service Unit		140:17		
Admissions and Records	1:44			
Agricultural Economics	:51			
Agricultural Extension	:07			
Bureau of Educational Research	1:16			
Bureau of Institutional Research	2:47			
Bursar's Office	5:29			
Business Office	22:06			
Civil Engineering	:25			
Dairy Science	3:28			
DHIA	46:09			
Economics	:06			
Education	30:01			
Forestry	1:17			
Horticulture	14:07			
Marketing	:11			
Navy Pier	3:21			
Statistical Service Unit	4:58			
Student Counseling Service	1:54			
Theoretical and Applied Mechanics		1:30		
			270:28	
				350:49

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 11:30 p.m. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for March.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

533 card read punch		10
Reads incorrectly	2	
Fails to read	3	
Cards off punched	1	
Card jam	1	
End of file not properly performed	1	
Fuse	2	
727 and 652 tape units and tape control		5
Rewinds improperly	3	
Tape spills in vacuum tube	1	
Tape damaged	1	
653 high speed storage, floating point, index registers		3
False lights	1	
Storage unit error	2	
650 console and magnetic drum unit		5
Storage selection	1	
Validity error	1	
Blank or multiple bits	3	
407 accounting machine		7
Printing incorrectly	2	
Spacing at wrong time	3	
Would not print	1	
Platen slipping	1	
655 power unit		1
Circuit breaker dropped out	1	
	Total	31

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
3/1/61	16:00			:06	1		(1) 533 not reading correctly.
3/2/61	12:22		1:28	:18	5		(1) Tape unit 2 did not do a rewind properly. (2) False storage unit lights. (3) Storage selection errors of some kind. (4) Card jam in 533 punch. (5) Fuse blew in 533 due to bad wire on board.
3/3/61	15:16			:05	1		(1) 533 read card column 14 incorrectly.
3/6/61	10:01	3:44	:50	:02	2		(1) Fuse blew in 533 due to loose screw in 533 standard #1 board. (2) Card feed stops due to dirt on card lever.
3/7/61	12:13		1:46	:05	5		(1) Validity check errors due to bad tubes. (2) Constant card feed stops. (3) 533 off punched cards. (4) 407 not printing correctly. (5) Constant card feed stops.
3/8/61	11:37		2:33	:09	2		(1) Digit 1 in words 3 and 4 not printing. Bad tube in 655. (2) 533 not properly doing an end of file.
3/9/61	16:12		1:06	:10	1		(1) Tape unit 2 damaged tape in a low speed rewind.
3/10/61	16:43		:01	:05	0		No error. Repair time for replacing a neon bulb.
3/13/61	11:40	3:45		:05	0		
3/14/61	14:39			:10	1		(1) Tape unit 1 did a low speed rewind instead of high speed.
3/15/61	14:33			:03	1		(1) Had four storage unit errors.
3/16/61	15:38			:03	2		(1) Many storage unit errors. (2) Tape unit 1 did not do a high speed rewind correctly.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
3/17/61	15:21			:07	0		
3/20/61	11:36	3:58		:00	0		
3/21/61	14:27		1:11	:24	2		(1) Circuit breaker dropped out. (2) Lost a binary bit in pos. 5 of program register.
3/22/61	15:23			:17	1	:24	(1) 407 continued to space due to burnt points on the space relay.
3/23/61	5:00	4:32	(:30)* :13	:04	1		(1) 407 would not print. Relay 1464 shorted.
3/24/61	8:38	(:36)* 8:00			0		
3/27/61	11:13	3:46	(3:40)* :09		2		(1) 407 continued to space paper. (2) Tape unit 2 spilled tape in vacuum tubes.
3/28/61	12:27		2:49	:56	1		(1) Platen slipping on 407. Circuit breakers had burnt points.
3/29/61	10:00		5:41	:04	2		(1) 407 spacing when it shouldn't. (2) Blank and multiple bits.
3/30/61	:32		14:38		0		Engineering time is for blank and multiple bits in all registers. Microphonic tube 4F in chassis 5.
3/31/61	9:06		6:25		1		(1) Random blank bits occurring in the distributor. Reason unknown. Trouble on 3/29 continued and diode 2-H was found to be shorting out.
							*Figures in parentheses are not included in the totals. The engineering was done on a machine but the 650 was operating properly and production done.
TOTALS	280:37	27:45	38:50	3:13	31	:24	

PART VII

GENERAL LABORATORY INFORMATION

Seminars

"The Order Code for the New Illinois Computer", by Professor Donald B. Gillies, Research Associate Professor of Applied Mathematics, Digital Computer Laboratory, University of Illinois, March 13, 1961.

"A Method of Dorodnitsyn to Reduce Differential Problems with Boundary Conditions at Two Points to Initial Value Problems", by Professor Jean Kuntzmann, University de Grenoble, France, March 20, 1961.

"Problems and Results Related to the Picard Theorems", by Professor W. K. Hayman, Imperial College, London, England, March 21, 1961.

Reports

Report No. 106, "Final Report - Flow-Gating", by Henry Guckel, T. Kunihiro and R. K. Crow, March 24, 1961.

Report No. 107, "An Approximate Stress Energy Tensor for Gravitational Fields", by Professor A. H. Taub, March 27, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	10	1	10.75
Visiting Faculty	0	0	-
Research Associates	2	0	2.00
Graduate Research Assistants	10	25	23.75
Graduate Teaching Assistants	0	5	2.00
Administrative and Clerical	7	1	7.33
Other Nonacademic Personnel	40	15	45.33
Totals	69	47	91.16

The Laboratory Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbaum, J. E. Robertson and J. N. Snyder.

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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - CIRCUIT RESEARCH PROGRAM

PART III - MATHEMATICAL METHODS

PART IV - DATA REDUCTION METHODS

PART V - ILLIAC USE AND OPERATION

PART VI - IBM 650 USE AND OPERATION

PART VII - GENERAL LABORATORY INFORMATION

April, 1961

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Physical Aspects of Machine Construction

(1.1) Chassis Modules

The castings for the first order of chassis modules are complete. This order consisted of 200 pieces or 100 matched male and female pairs.

The order for terminal strips for the 100 pairs is complete and the strips have been delivered to the company that has the machining and assembly order.

The delivery of 43 of the 100 completed pairs was made in the month of April from the machining and assembly company.

Three each of 4 different sizes of completed chassis modules were tested for contact resistance, closure, interchangeability, and wire-wrap connections with #22 and #18 wire. The contact resistance proved to be between .002 and .003 Ω. The closure was checked on the large chassis to compare the side pins with the top and bottom. The side pins close 75% of the way when the top and bottom are closed. This is perfectly safe. Interchangeability showed up some lack of hinge uniformity and pin alignment. The wire-wrap seems to be very good for the #22 and #18 wire.

(1.2) Air Conditioning

The heat exchanger-compressor combination unit has been delivered and is in place on the roof of the Laboratory.

The two air-handling units have arrived and are awaiting basement preparations for their mounting.

The transformer room and power supply room exhaust fans have been changed to outside exhaust, making room for the input air ducts for the computer.

(1.3) Shop progress is as follows:

32 chassis complete

53 chassis complete except for installation in aluminum frames

8 chassis waiting for diodes and inspection

16 chassis being wired.

(C. E. Carter, T. E. Kerkering and Shop)

2. Drawings

(2.1) The block layout and specifications are complete for the Exponent Arithmetic Unit. This consists of about 7 large chassis and 3 small chassis.

(2.2) The block layout and specifications are complete for the first of our slow-speed circuits. This consists of 2 large chassis.

(H. E. Lopeman and S. P. Krabbe)

3. High Impedance Twisted Pair Tests

Twisted pair cables, with characteristic impedances Z_0 greater than 93 ohms, were found. A.W.G. #22 wire with teflon insulation ($\mathcal{E}_r = 2.0$) was found to give the following results:

Insulation Thickness	Z_0	C
.010 in (nominal)	120 Ω	13 μμfd/ft
.015 in	140 Ω	11.5 μμfd/ft
.020 in	160 Ω	10 μμfd/ft

These results were verified experimentally by using the cables in terminated cable drivers on the MAU test rack. Measurements indicate the same capacitance per foot when the cable is wound at 1/2, 1, or 2 turns per inch. The time delay in such cables is 5.5 ns per meter.

(M. Melman)

4. Noise Problems

Several emitter-followers were wired in series, connected with unterminated twisted pair cables. Rise time degradation was verified with calculations using the $c \cdot v = i \cdot t$ relationship. In order to maintain a rise time of 20 ns out of an emitter-follower whose R = 3K, the output capacitance can be only 37 μμfd. The equivalent capacitive load for a non-restoring circuit output is 11 μμfd.

Line Reflections

Cascaded emitter-followers connected by several feet of single wire or twisted pair cable exhibit irregularities in their rise and fall times. Experimentally it has been verified that certain overshoots and steps are due to reflections on the lines. These reflections are caused by impedance mismatches at the sending and receiving ends of the line. The steps in the positive leading edge of the pulses indicate that $Z_{in} < Z_0$, for a negative reflection factor. The output impedance Z_{out} of the emitter-follower, in steady state, is also less than the Z_0 of either a single wire or a twisted pair. $Z_{out} \approx r_e + R_s \frac{1-\alpha}{\alpha}$ where R_s is the impedance of the source driving the base. For a restoring type emitter-follower, $R_s \approx 1K$. For a non-restoring logic emitter-follower, assuming $R_s \approx 50$ ohms (the Z_{out} of the previous emitter-follower), $0.93 < \alpha < 1$, and $r_e \approx 20$ ohms, then $20 < Z_{out} < 95$. The dynamic impedance looking into the base of a

transistor is nonlinear and no expression is known defining Z_{in}. Experimenentally it is seen that for some transistors the input impedance is low when higher frequency components are present. The insertion of a resistor in series with the output emitter wire such that $Z_{out} + R = Z_0$ does improve the leading edges.

Noise Pick-up

For single wire;

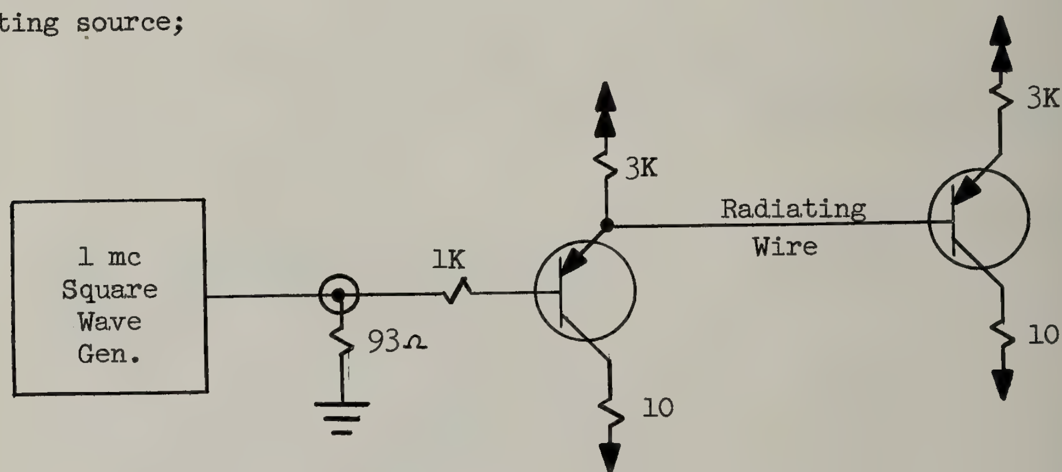
$$Z_0 = 138 \log \frac{2h}{r}$$

$$h = 1 \text{ inch}, \ r = .012 \text{ inch}$$

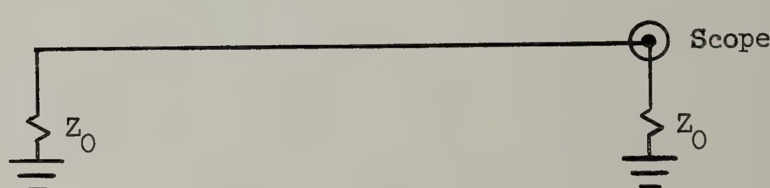
$$Z_0 = 300 \text{ ohms}.$$

The following pick-up noise measurements were made.

Radiating source;



Receiving circuit;



Conditions:

Length of wires = 2 feet

Height above ground = 1 inch

Rise time = 19 ns.

Pulse amplitude = 4 volts

I Radiator: Single wire

Receiver Induced Volts

Receiver	Single Wire	Twisted Pair
Distance between wires		
1/8 in	.27 v	.08 v
1/4	.15 v	.04 v
1/2	.08 v	.03 v
1	.05 v	.02 v

II Radiator: Twisted Pair

Receiver Induced Volts

Receiver	Single Wire	Twisted Pair
Distance between wires		
1/8 in	.16 v	.04 v
1/4	.09 v	.025 v
1/2	.06 v	.015 v
1	.03 v	.01 v

(M. Melman)

5. MAU Chassis Tests

Tabulations of expected DC voltages on the A, S and QRM chassis were completed. Work was begun on DC checkout of these chassis.

(A. P. Stone)

6. Layout of the Delayed (or Arithmetic) Control

The month was devoted to making a second layout of Delayed Control. This was necessary because the signal distribution system in the first layout, which was completed in March, was found to be unsatisfactory. Its primary fault was the use of non-restoring logic and emitter-followers for the collection of requests and the distribution of replies in a system where many of the leads were over 3.5 feet long. It has been experimentally determined that this combination of non-restoring logic with open wire connecting leads in excess of 2 feet will give rise to noise problems and the possibility of system oscillation.

To overcome these difficulties the second layout uses a system in which any lead over 2 feet long is shielded and is driven from a collector. In order to incorporate this system, approximately 1,000 transistors have been added to the Delayed Control in the form of cable drivers and restoring circuits. In anticipation of possible additions of this type in the future - as more of the details of the circuits postulated in this layout become known - another 700 transistor spaces have been uniformly distributed throughout the new layout.

This layout uses all of the Q, A and S level chassis in bays 8F, 9F, 15F, 16F, 17, 16R, 15R, 14R, 11R, 10R, 9R and 8R as well as A and S in 13R. It also uses all of the Q, A and S level chassis in center wall bays 6, 7, 8, 16F and 16R. Part of the space in bays 8F, 8R, and 6C includes EAU and end connection logic.

The gate and selector logic is contained in the center wall bays designated above. This logic includes the primary combining AND circuits for each gate and selector option. In the case of the MAU it includes the

cable drivers for these gates and selectors. For the EAU the primary gate and selector drivers are located on the EAU chassis in bay 7R. In all cases the center wall contains the cable drivers necessary for distributing the replies to logic in the reply areas.

Most of the control status memory elements are located in chassis Q8R and Q8F. Included in these chassis are the primary combining AND's for setting the memory elements and the cable drivers necessary for distributing their outputs and replies. The EAU status memory elements and status signals are located in chassis A8R and S8R. The cable drivers necessary to distribute these signals are also located in these chassis or in A9R and S9R. The cable drivers needed for the distribution of end connection signals are located at the source of these signals.

Except for the multiply and divide loops, to be mentioned later, the sequencing logic for delayed control is divided into 4 sections. At the center of each section, in an A level chassis, is a "request area" where AND circuits with cable driving outputs are used to collect requests for a given function. At the periphery of each section are several "reply areas" which contain restoring logic to provide replies and signals used for conditional logic to the control areas. Between the request and reply areas are the sequencing control areas oriented so that each control area's AND-NOT is as close to the request area as possible. It is felt that with such a layout, the leads from control area to request area and from reply area to control area will be within the 2 foot limit. Within Delayed Control there are 4 request areas, 13 reply areas and 89 control areas.

The layout described herein does not give a special speed advantage to any particular operation except for the iterative loops of multiply and divide. The control areas which represent these loops are located in A8R and S8F respectively. Their gate and selector requests are sent directly to the primary combining AND's. Likewise, they receive their replies directly from level restorers located in the center wall.

Not all of the circuits postulated in this description are completely designed at present. The over-all layout cannot be made final and released until the exact number of transistors involved in each circuit in question is available.

Two different sets of charts have been compiled which should speed the process of making the layout of Delayed Control final once all the details of the cable driving circuitry are known. The first set of charts is based on requests, replies and status signals. In the case of a particular request the first set shows all of the control areas in which it originates and the request areas where it is collected. For a particular reply or status signal it shows which reply areas contain restoring circuits for this signal and the control areas which each restoring circuit feeds. This set of charts also lists the number of cables required for each reply or status signal and the reply areas which each cable feeds. The second set of charts is based on the request and reply areas. They show all of the signals which appear in each area and the control areas in which they originate or terminate.

Speed Independence

One of the objectives of the logical design group has been the creation of a speed-independent arithmetic control. Unfortunately, this objective has not been attained due to the inability of existing circuitry to meet the fanout requirements of the control logic. Most reply signals and some status memory element outputs have fanout requirements that can be obtained only through the use of logically equivalent but physically separate identity elements such as emitter-followers, level restorers and cable drivers. If the circuitry were to operate in a speed-independent manner, proper operation would be obtained even when the ratio of the time delay through the slowest to the delay of the fastest of these identity elements was infinite. In the actual circuitry being used, proper operation is obtained when this ratio, in the worst case, is as great as 8.

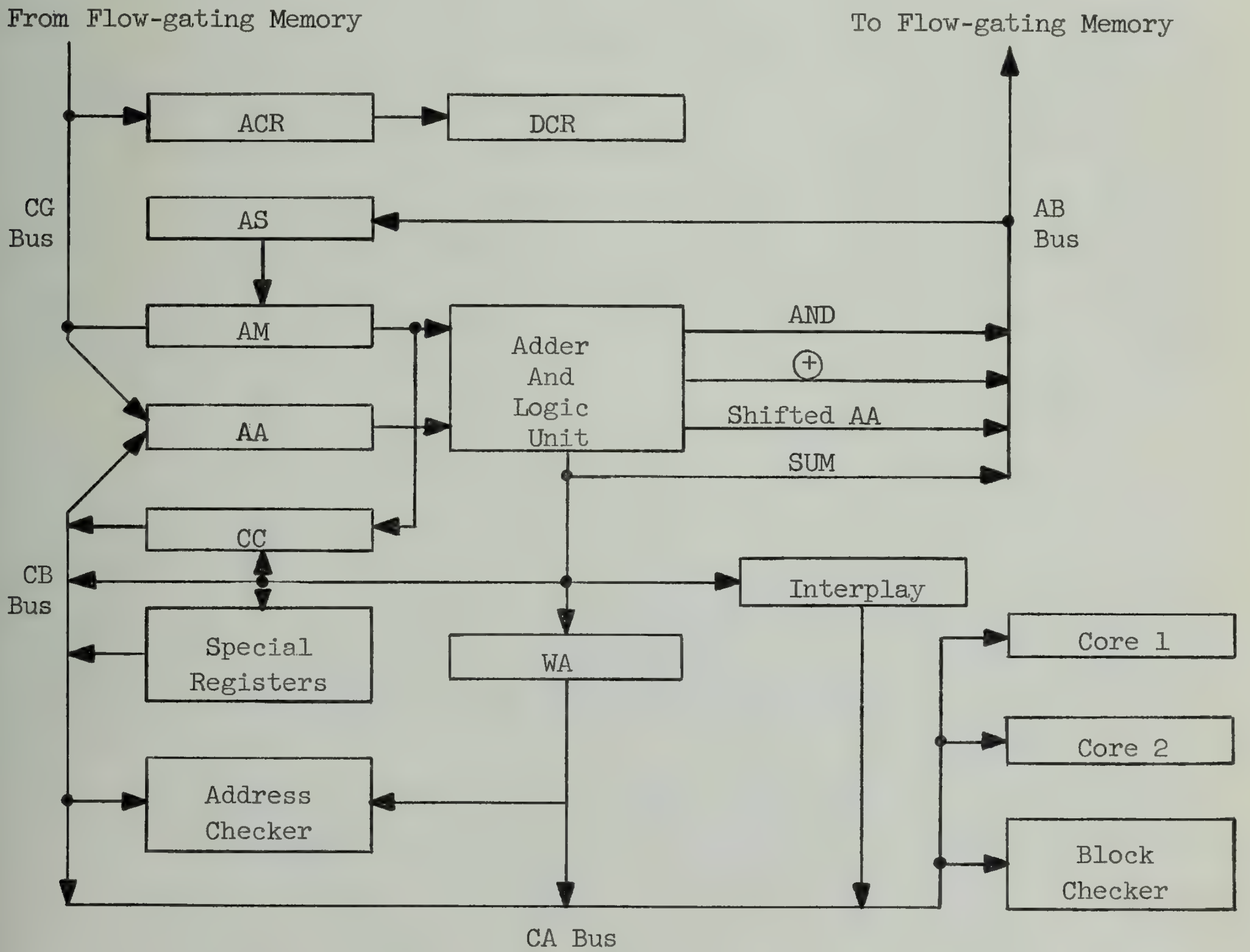
Since most of the reply system is not speed-independent, an investigation was made into the effect of eliminating all replies that could not be handled in a speed-independent manner. Proper timing of operations would then be obtained through the use of a delay line or other delay element at each of the 89 control points. It was found that approximately 2200 transistors could be eliminated from the MAU,

EAU and Delayed Control portions of the machine. Although such a reduction would greatly simplify the layout of Delayed Control, it was decided that the problems associated with a non-speed-independent reply system were fewer than those associated with the delay type solution. One of the reasons for this decision was the realization that there are few, if any, machine errors more difficult to find than timing errors and in the delay solution there would be 89 delays. Equally important is the fact that a delay solution would be at the expense of asynchronous checks on all requests.

(H. Aiso, J. O. Penhollow and R. E. Swartwout)

7. Advanced Control

The principal registers and paths for advanced control are shown on the following diagram:



Registers ACR, AS, AM, AA, CC and WA each contain 13 bits, as do the buses CG, AB, CB, CA and the adder output bus AD. ACR is the advanced control order register and DCR is the 7-bit Delayed Control Order Register. Registers AS, AM and AA, the Adder and Logic Unit (AALU) and the AB and AD buses are collectively referred to as the Address Arithmetic Unit (AAU). Register AA is always connected to the AALU, and has a clear gate which is not shown. The input to the AALU shown from AM is controlled by a selector and a controlled carry into the least significant adder stage and may take on values $\pm$ AM, $\pm$ 1, 0, -2, -3. Register CC is a double-rank control counter, whose value is normally the address of the next order word in sequence. In the case of the short loop count and jump to last word of orders, CC is not backed up unless a core memory fetch is required to obtain that word of orders. Register WA holds the address of any delayed control store order by-passed by Advanced Control and not yet completely executed. When WA is filled, the address checker is used to lock out the memory location referred to by WA until the store order is completed. Special registers will include the interrupt and mask registers, status flipflops for input-output devices, error indicators etc. There is the possibility of a 3-way competition for the use of each core memory — the competitors being Advanced Control (the possessor of CB), Out-Write Control (the portion of control responsible for storing the OUT register in the address given by WA), and interplay. The winner of the memory competition then competes for CA and transfers its address to the proper core memory. The block checker is used to protect blocks of 256 words each, in core memory, from illegal references by Advanced Control and Out-Write Control.

This register and bus arrangement allows many concurrent operations. Since CA is only required for the very first part of a core memory cycle, it can be time-shared between the 3 controls mentioned above. For orders which do not refer to memory, CC can be connected to CB, so a word of orders can be pre-fetched in parallel with the execution of some order. The transfer of ACR to DCR is not done at any one step in order execution, but rather as soon as DCR is free. In parallel with the transfer of AD or AB to any destination, the next order can be read to ACR, and the transfer AS to AM, if required, is done in parallel with the read-out of a quarter word to AA.

A detailed logical diagram of the portion of Advanced Control shown here (except for the shift mechanism) together with a tentative layout to estimate the effect of lead length restrictions has been prepared by R. R. Shively. File No. 371 entitled "Advanced Control" by R. R. Shively was prepared during the month.

(D. B. Gillies, R. R. Shively and C. Wallace)

8. Applications of Slow Circuits

A 13-bit control counter (to add one to the address) was designed for Advanced Control, using the new slow circuits (Drawing No. C-1102). The specifications for the counter called for a repetition time which could be as long as 3/4 microsecond, and it was therefore felt that if greater economy in price and transistors could be achieved with slow circuits rather than with the standard fast circuits, then the former would be used. The counter is double-rank, uses single-wire gating and, together with its drivers, occupies two 18" x 12" chassis. It will be built early, and initially will be tested with the core storage unit before being installed in the computer proper.

The experience of this type of logic was written up in File No. 369 entitled "Some Notes on Logical Design Using the New Slow Circuits", and is intended as a preliminary guide for those who wish to use these circuits for logical design.

(M. Faiman)

9. Design of Slow Circuits

The tolerance analysis for slow circuits is being done over, using new semi-conductor data from Files 362, 364 and 365. These files represent transistor, zener diode and diode specifications respectively for slow circuits.

(M. D. Freedman and L. J. Peek)

10. Core Memory

One week's time and 400 transistors were lost during this month due to a momentary short-circuit of the AC power line to the -5 v DC power buss. The short allowed power line current to flow through the collectors to bases and emitters of emitter-followers by way of an 0.5 μfd capacitor which references the power line to the DC reference. Of the transistors ruined about 80% were open e-b while the remining 20% were shorted.

After replacement of transistors (and a few diodes) the model memory ran as before, thereby indicating the circuits to be relatively tolerant to different transistors.

Continuous running of the memory will be attempted for the next 6-8 weeks.

(S. R. Ray)

A scheme has been devised, based on the system presented in the Address Decoder, Drawing D-984, for decoding the 12-bit address to either 4096 word memory in such a manner that the number of the X driver and the Y driver are derivable easily and that the position of the core stack terminals connected to the drivers in question can be determined easily. A by-product of this scheme is the relative ease with which the 12-bit memory address can be constructed given a specific X driver number and Y driver number.

A minor revision of the Address Decoder, Drawing D-984, was required by this scheme. The numbers of the X drivers and the Y drivers on Drawing L-917 and on the physical layout of the 4096-word memory require some revision also as a result of the scheme.

(J. L. Muerle)

11. Magnetic Drum Memory

The purchase of two magnetic drums from Vermont Research Corporation, Springfield, Vermont, was approved during the month. The two drums will be delivered in September and December, 1961.

A detailed block diagram of the Magnetic Drum Memory has been prepared. From it, an estimate of the number of transistors in the various parts has been made as follows:

Read-Write	172 x 14	2408	
Head Selection	64 x 14	896	
Parity Check		166	
Control Input and Addressing		278	
Sector Selection		710	
Bit Timing		298	
Sync. Alarm		98	
Total for Magnetic Drum Memory		4,854	transistors

(H. C. Brearley)

Drivers have been designed for the select transistors of the head selection switch as shown in Figure 1. In column select, the requirements are high voltage swings (at least as high as the head drive voltage) and high currents (to attain and maintain saturation in the selected transistors). A large fanout is necessary because selection switches for all 14-bits are to be driven in parallel. Slight modifications of the circuit in Figure 1 may be needed, depending on the final choice of the transistor types.

Measurements are being made with the 32 prototype read-write heads that have recently been received from Vermont Research Corporation.

(P. V. S. Rao)

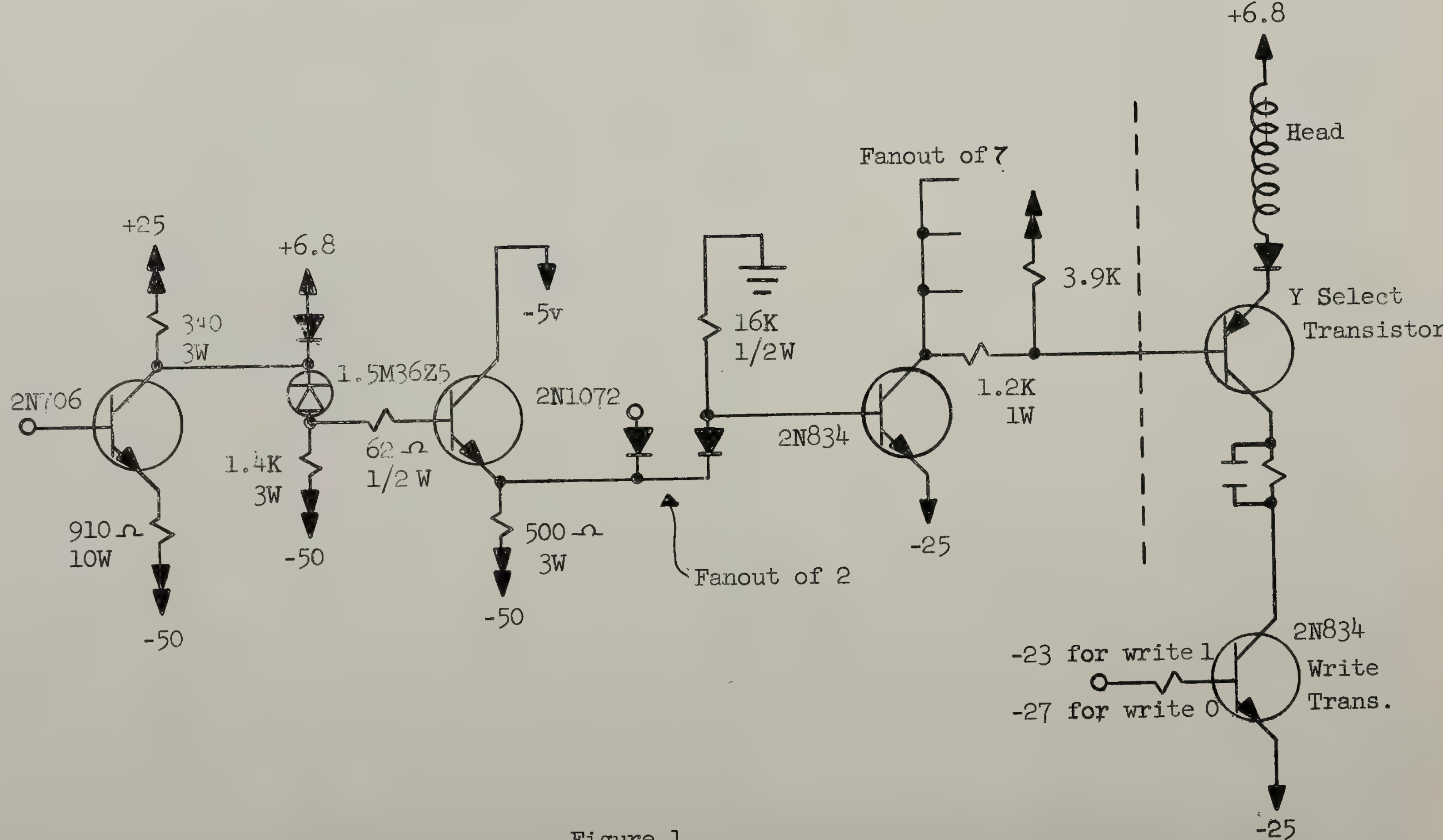


Figure 1

Y Select Transistor Driver with a Section of the Selection Switch

The reduction of the Magnetic Drum Memory block diagram to detailed logic diagrams using the "slow" circuits (Drawing C-1102) was begun. Circuits for the sector counters, the comparison circuit and for checking the absence of one or more origin pulses or sector pulses were developed.

(M. Falleni)

A variable frequency pulse generator for use in drum write experiments was designed and tested.

(C. N. Liu)

12. Magnetic Tape Memory

The base 7 conversion discussed in the February and March Progress Reports can be done as shown in Figure 2. The heart of the system is the block labelled "conversion circuit", which embodies the equations governing the conversion. The auxiliary register stores information to be carried from one stage of the conversion to the next. The Control gates the information from the register to the proper input lines, x_i, of the conversion circuit (each of the x_i represents three bits). The Control also routes the resulting three-bit output to the proper location in the bottom 12-bit register. Four cycles of operation of this circuit are required to effect one tape character conversion. The 12-bit character thus formed must next be operated on by an error-correction matrix (not shown) which generates six check bits, resulting in an 18-bit tape character.

Before going further with the development of this scheme it seems desirable to have another look at read-write circuits for magnetic tape recording. In particular, it is necessary to find just how high a data rate we can handle in practice, so that the operating speed requirements for the conversion circuit will be known. Work was started to this end in April.

(R. L. Cummins)

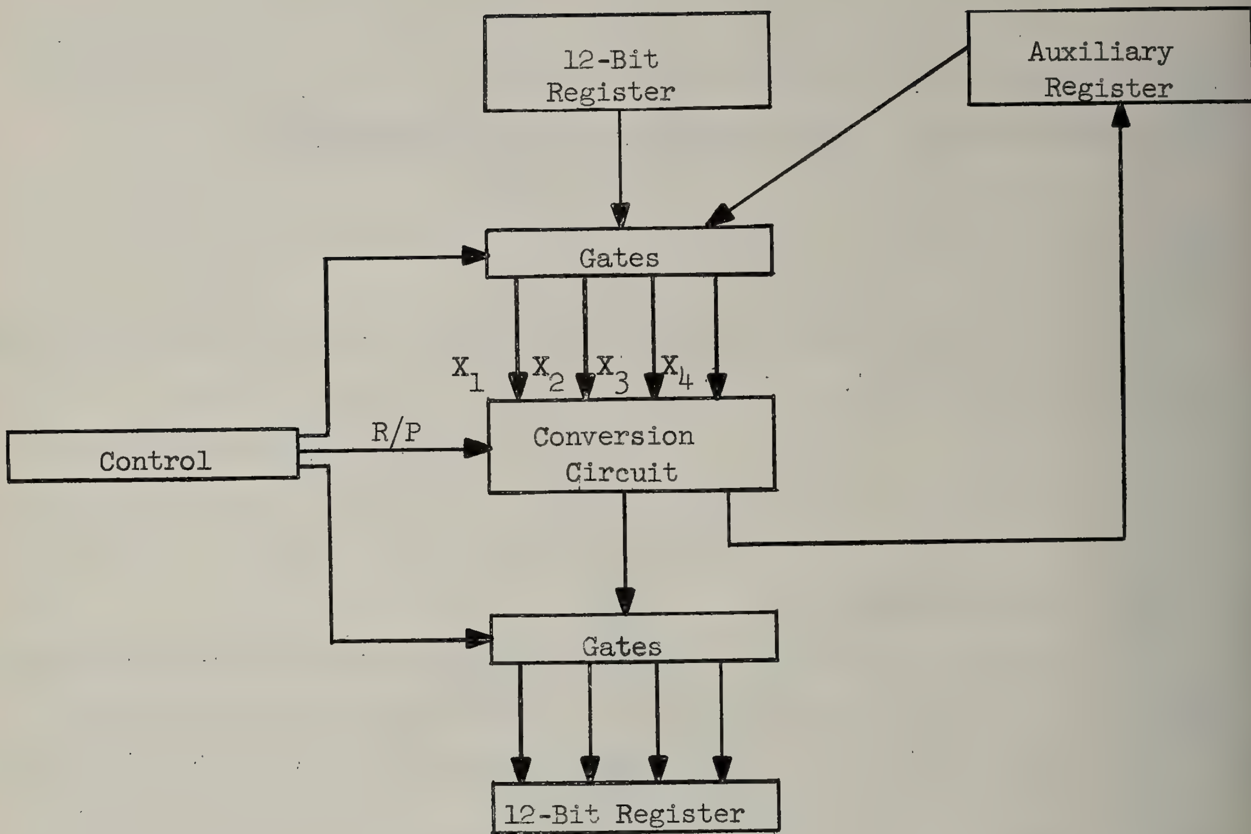


Figure 2

Base 7 Conversion Block Diagram

13. Paper Tape Equipment

The Elliot reader has been delivered, and has performed satisfactorily on continuous reading tests. Circuits to enable it to be started and stopped rapidly are being made at the Coordinated Science Laboratory. The discrimination between hole and no-hole with 5-level ILLIAC oiled tape is excellent over a wide range of lamp and photocell supply voltages.

An order has been placed with Tally Register Corporation for the paper tape editing equipment.

(C. S. Wallace and Personnel of the Coordinated Science Laboratory)

14. Interplay

The attempt to design a system which would not monopolize the memory unduly during input and output ran into severe difficulties, in that if interplay asks for a memory only when ready to use it, it may have to wait for one cycle before getting access. During output to the drum, therefore, a time in excess of four memory cycles could elapse between when interplay could accept another word to be output and when it got it.

This time (of more than 7.2 μsec, taking a memory cycle of 1.8 μsec) is dangerously close to the drum word period of 7.8 μsec. A different system involving some slight waste of memory time, but reducing the access time for drum output to 6.9 μsec is being designed.

(C. S. Wallace)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

R. Crow worked on a fast counter for the shift-register project mentioned in the February Monthly Progress Report. H. Guckel and C. Afuso also spent most of their time on this project. The sections below give most of the findings.

2. Counter Design

The basic idea was to build a push-pull gating circuit logically equivalent to Figure 1. This should at least give a good indication of the system speed which one might expect in a general logical set.

Using Afuso's push-pull gating system, with unbalanced Zeners and a standard difference amplifier flipflop with Zeners cross coupling,

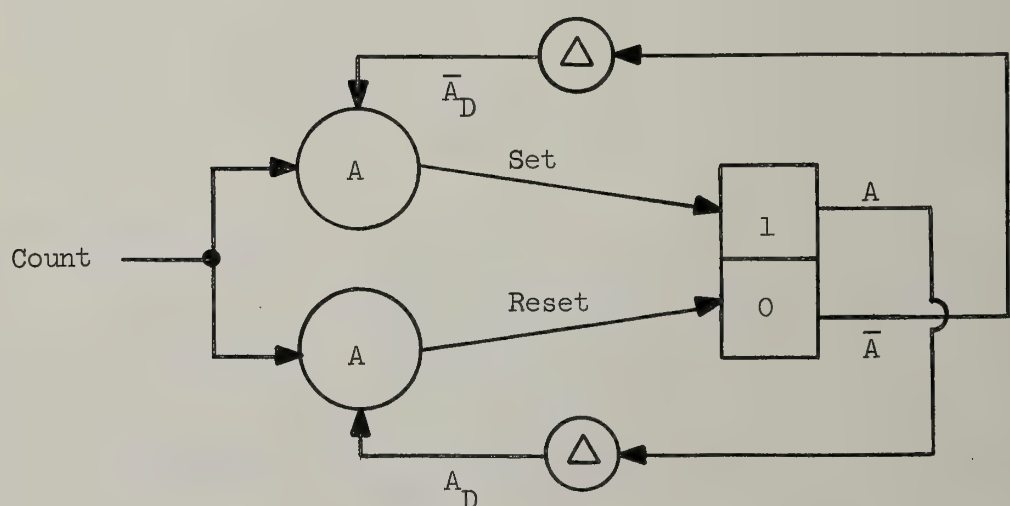


Figure 1

Logical Design of the Fast Counter

the circuit of Figure 2 was obtained. DC values of voltages are easily maintained to good tolerance, the only critical components are the Zener diodes: 7.5 v and 6.8 were used for the "unbalance" into the AND gates. These have to be matched sets.

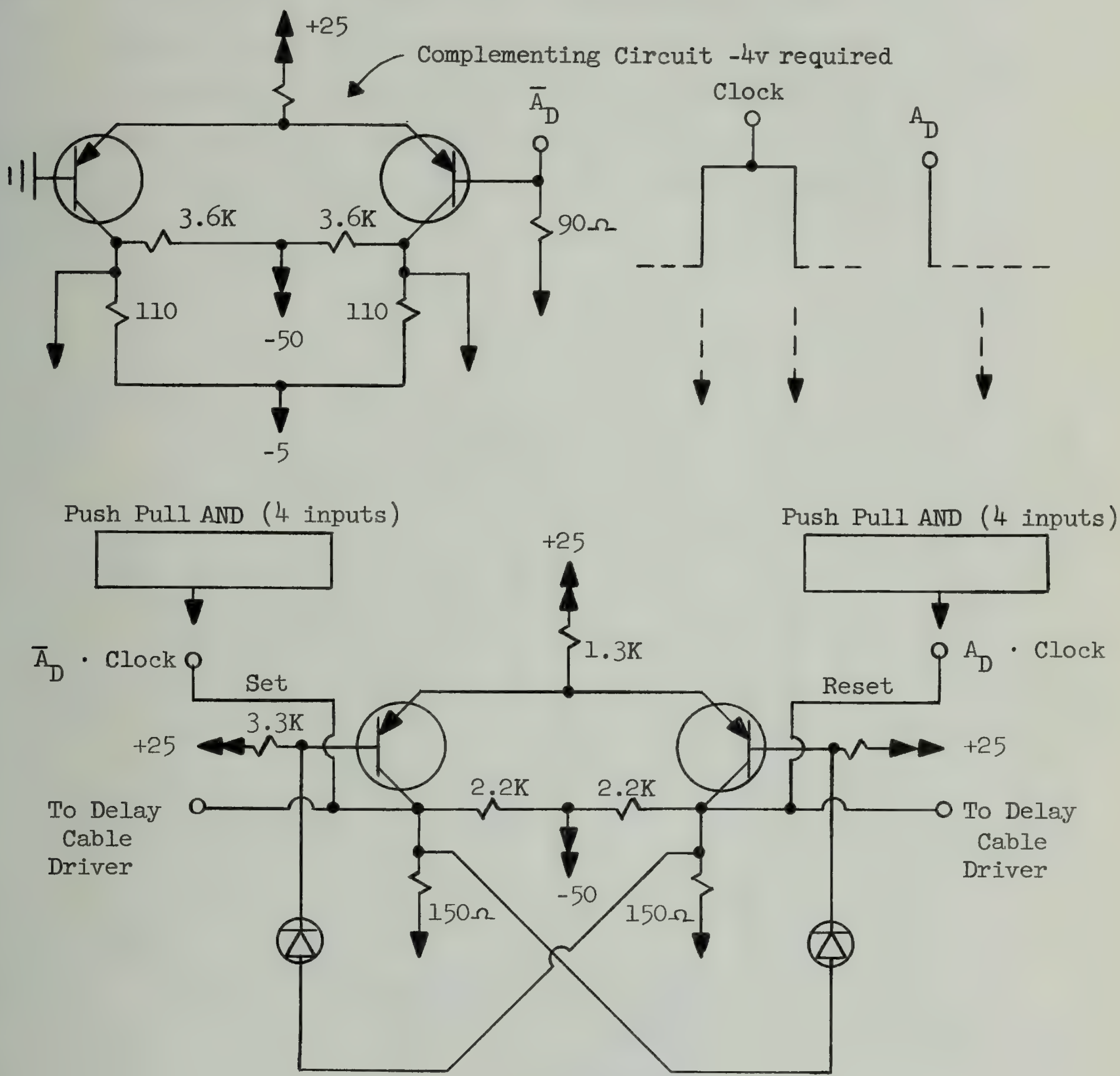


Figure 2
Push-Pull Gating "Delay" Counter

The circuit responds to slow inputs with a 20 mμsec. delay for D in Figure 1. However, the circuit does not trigger with a 50 mμsec. input and a 40 mμsec. delay. With the flipflop transistors removed and proper inputs A_D and $\overline{A_D}$ patched in, the AND circuit delivers voltage pulses to the flipflop collectors with rise times of the order of 10-15 mμsec. However, with the flipflop transistors in, the pulse at the collector is very poor. For the moment being this type of counter was abandoned.

The very simple circuit shown in Figure 3 has been built, and some very preliminary tests were run.

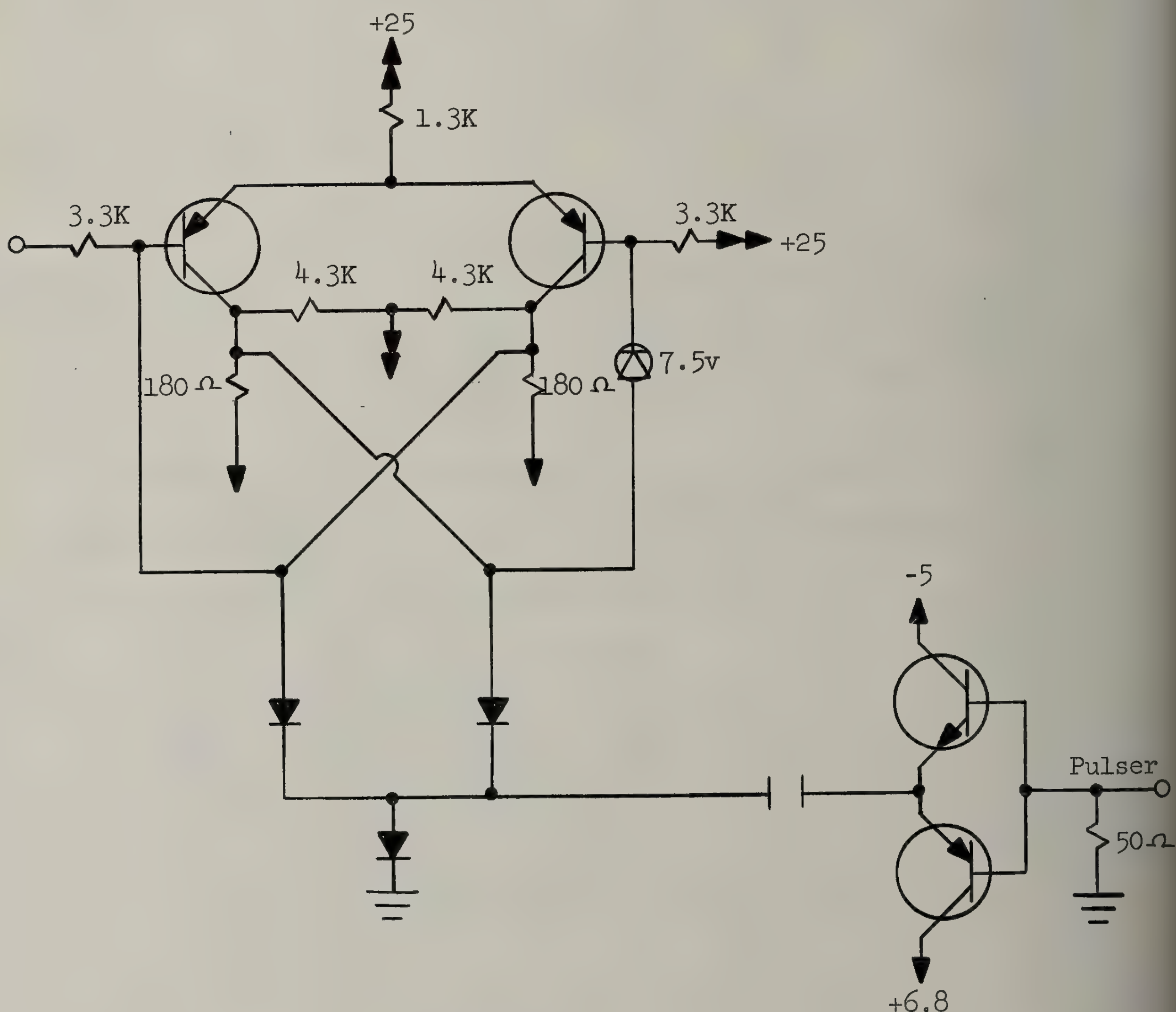


Figure 3
Simplified Counter

Using the fast HD 100 diodes, the "trigger steering" at the collectors seemed effective - and the rise time as good as could be observed with the 517 scope. However, this circuit would not trigger with a 37 mμsec. pulse of 2 v magnitude at the input diodes, even though the steering was effective. More work must be done to determine why the basic flipflop is so difficult to trigger.

A scheme which would produce a truly symmetrical flipflop - using NPN-PNP transistors is shown in Figure 4. In this circuit, all the reverse bias ratings are compatible with the TI 2N250-2N251 pair (N100-N101). The circuit of Figure 4 has been built but no testing has been done as yet.

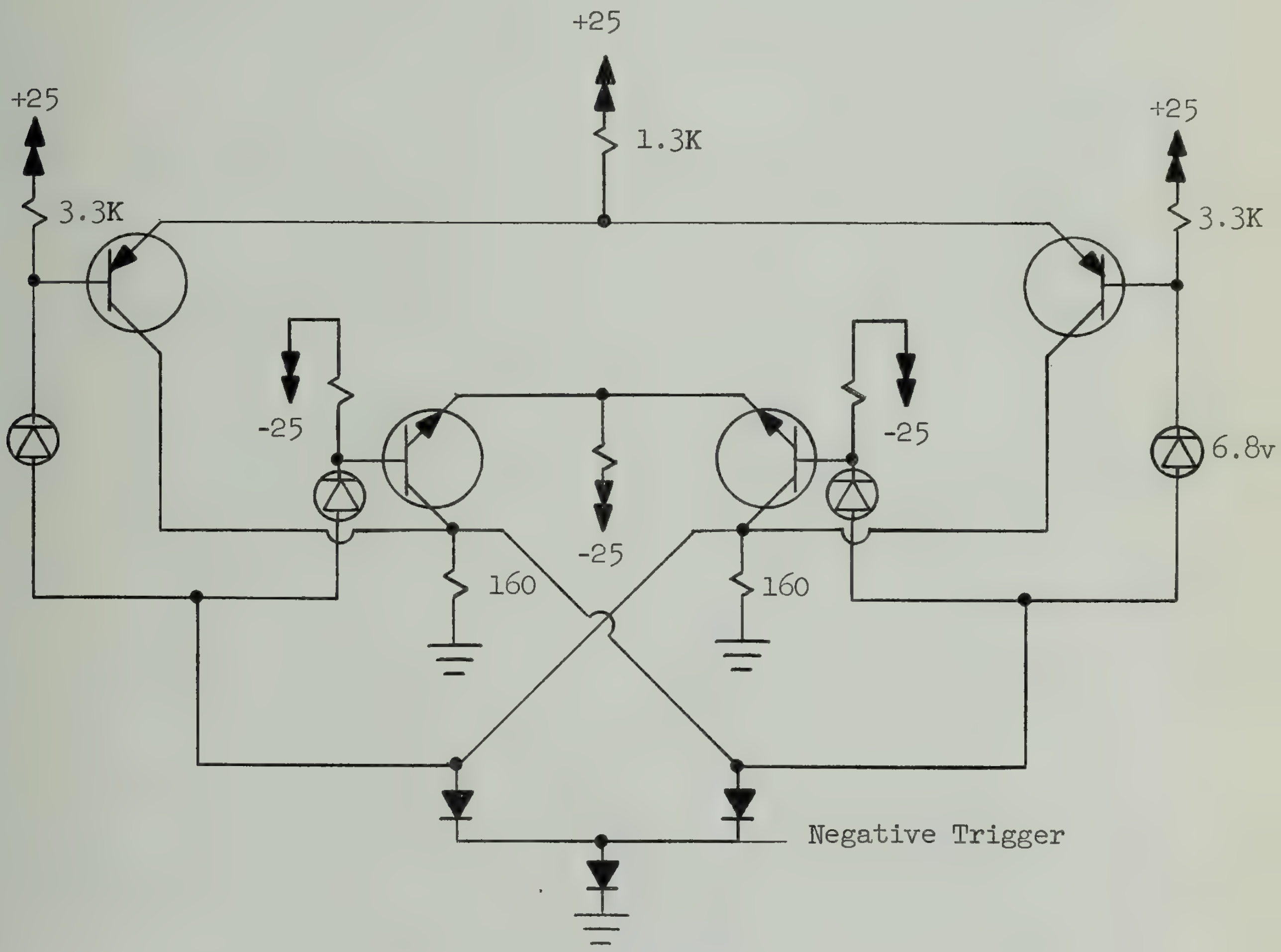


Figure 4
Symmetrical Flipflop

3. Fast Shift Register

This month, most of the time has been spent building a shifting register. The actual circuit has been changed from the original one in the following ways:

i) To improve the low input impedance of the difference amplifier, an emitter-follower is attached in front of each difference amplifier.

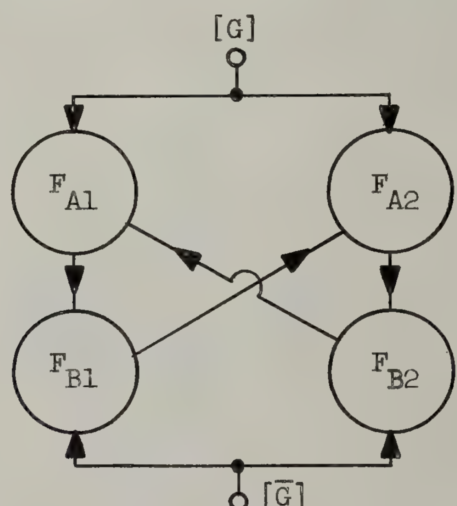
ii) Because of this modification, each F-element circuit now requires 20 transistors. Therefore the original 4-bit register was changed to a 2-bit register.

By attaching an emitter-follower to each difference amplifier, a self-oscillation arises easily. To avoid the oscillation AC grounding becomes very important: decoupling capacitors are inserted at every AC ground point.

Coincidence of DC levels is important in connecting the whole system, because in the AND and OR circuits, (as used in F-elements), two inputs S and G go into the same difference amplifier.

The circuit for a new F-element is shown in Figure 5. $\overline{G}$ is supplied with a DC prebias voltage.

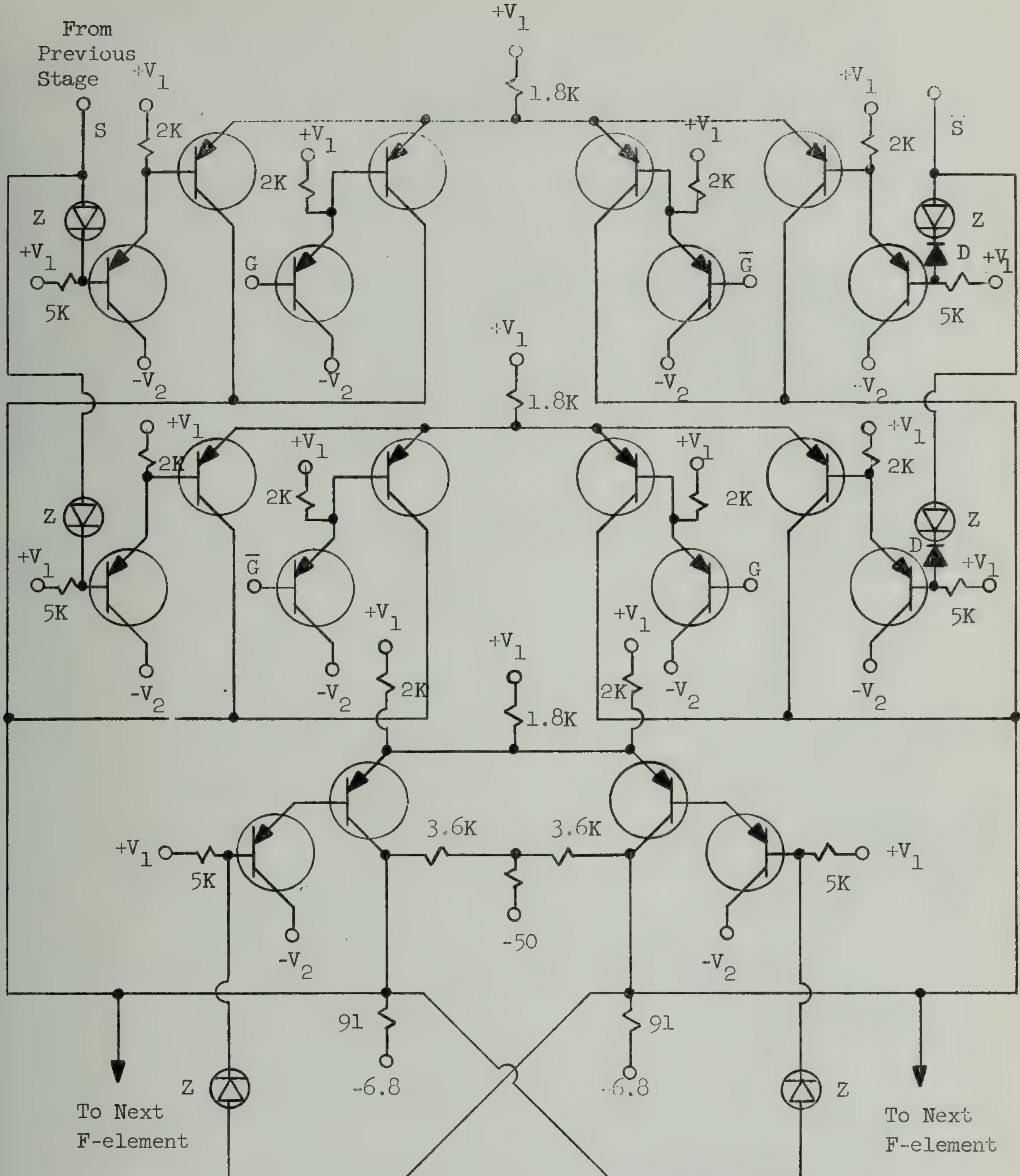
In the register four F-elements are connected as shown in Figure 6 below. No test results are available yet.



[G] means $(G, \overline{G})$

$[\overline{G}]$ means $(\overline{G}, G)$

Figure 6
F-Element Register



$V_1 = 25v$

$V_2 = 5v$

Z: 6.8 volt zener diode

D: inserted to produce the prebiased voltage S-577G.

Figure 5

Emitter-Follower F-Element

PART III

MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Monte Carlo Methods in Quantum Statistics

A program to calculate the quantum mechanical partition function for a simple system has been written. This program computes an approximation to the partition function by evaluating an associated "conditional Wiener integral", using a sampling scheme described in File No. 361. The system is two dimensional and it consists of two particles in a box with an interaction, potential $V(r)$ between two particles separated by a distance r described as follows:

$$\begin{aligned} V(r) &= \infty && \text{if } r < a \quad, \\ V(r) &= -v && \text{if } a \leq r < b, \\ V(r) &= 0 && \text{if } b \leq r \quad, \end{aligned}$$

The box is characterized by a potential function V_{box} which is infinite for either particle outside of the box and zero for both particles inside of the box. The total potential for the system is $V_{tot} = V_{box} + V(r)$. The quantities a, b, $\frac{v}{kT}$, and the box volume are easily varied parameters for the program. This program is now being code checked. A test is also being made of the random normal deviate generator which is a subroutine for this program.

(L. D. Fosdick)

PART IV

DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)1018 of the Atomic Energy Commission)

1. Local Pattern Recognition on Digitized Bubble Chamber Negatives

The over-all data rate for automatic scanning depends predominantly upon rapid classification of local areas (domains of 8-32 cell divisions on edge) of the negative. Pair count measures, discussed previously in these reports, are being used to provide "test scores" for statistical classification of domains.

In the human scan method the domains to be scored by the computer (Illiac) are prespecified by a trained scanner of bubble chamber negatives. The scanner classifies rectangular domains of his selection into one of twelve categories:

(1) minimum beam track, isolated.
(2) subminimum (i.e. poor chamber operating conditions) beam track, isolated.
(3) parallel tracks.
(4) confluence of 2 or more parallel tracks.
(5) secondary track, lightly ionizing.
(6) secondary track, heavily ionizing.
(7) delta ray.
(8) tight electron spiral (or core of larger spiral).
(9) loose electron spiral.
(10) vertices (real or pseudo) of 3 or more prongs.
(11) flume, globs, fiducial marks.
(12) background.

The domains are recorded sequentially in normal scanning order: along a track, spiraling out from the core of an electron spiral, or designated as without sequence order, as is the case for background, globs, isolated tight electron spirals, etc. The scanner designates for each rectangular

domain to be examined a sequence number (S), Cartesian coordinates (X_c, Y_c) of the center of the domain, width and length (ΔX, ΔY), type number (T), that is one of the above twelve categories, and finally a previous reference number (R), should this domain have been previously recorded as part of another sequence, (e.g., a vertex domain).

A test bubble chamber negative 512 x 512 cell divisions, where 1 track width = 1-2 cell divisions requires typically 150-200 domains to cover all areas of interest. A first data tape from one picture has been prepared, and work is continuing to provide a sample of 800 domains for statistical analysis.

Given for each domain a scoring algorithm (pair counts) and a statistical classification scheme (factor analysis), it is entirely relevant to ask whether the computer requires of the human scanner:

i) classification of each domain;
ii) coordinates, size of the domain;
iii) sequence information (local tangent to sequence trajectory, displacement from last domain, etc.).

To test the conjecture that the computer program can adequately classify domains without prior human examination of the picture, a data tape generator has been written and run which selects domains at random, with a uniform distribution of lengths and widths, (e.g. ΔX = 8-22, ΔY = 8-38 cell divisions). An output tape of 600 scored domains is now being processed by factor analytical routines. Prior deletion of essentially white domains (< 5 black cells) has proved necessary.

The pair counts $N_{\alpha\beta}$ ($\alpha\beta$ = 1, ..., 16), for example the number of horizontal gradient pairs of the form $\boxed{X \mid \cdot}$, are not necessarily optimum for subsequent factor analysis. Probabilities $p_{\alpha\beta} = N_{\alpha\beta}$ number of pairs in rectangle, conditional probabilities, and information measures (e.g. $p_{\alpha\beta} \ln p_{\alpha\beta}$) are also being tried. These newer scoring conventions are referred to as normalizing transformations of the original domain scoring tape, that is, modification of each domain independently of all other domains.

2. Artificial Pattern Generation

The program to generate by Monte Carlo methods a pattern of blacks and whites in a prescribed rectangular domain consistent with a priori prescribed pair counts is being extended to study strategy of growing patterns. Originally a Chi-Square measure

$$\chi^2 = \sum_{\alpha\beta}{}' \frac{(N_{\alpha\beta} - \bar{N}_{\alpha\beta})^2}{\sigma_{\alpha\beta}}$$

where $N_{\alpha\beta}$ = 16 pair counts with means $\bar{N}_{\alpha\beta}$, standard deviations $\sigma_{\alpha\beta}$ was used. Steps were taken consistently toward lower χ^2, However for a given type of domain, e.g. beam tracks, the $N_{\alpha\beta}$ are not statistically independent, but instead highly correlated. As a strategy metric χ^2 should reflect this. Accordingly χ^2 has been extended to:

$$\chi^2 = \sum_{\alpha\beta,\gamma\delta}{}' (N_{\alpha\beta} - \bar{N}_{\alpha\beta})\, G_{\alpha\beta,\gamma\delta}\, (N_{\gamma\delta} - \bar{N}_{\gamma\delta})$$

where $G_{\alpha\beta,\gamma\delta}$ can be taken as the inverse of the correlation matrix. Furthermore, the entire domain can now be examined cell by cell, and that move (black $\leftrightarrow$ white interchange) made which minimizes the next value of χ^2. Provisions to avoid local minima of χ^2 are also being introduced. A strategy matrix $G_{\alpha\beta,\delta\gamma}$ will be considered optimal if from a collection of random patterns, the number of moves to lock into a pattern with $N_{\alpha\beta} = \bar{N}_{\alpha\beta}$ ($\alpha\beta$ = 1, ..., 16) is minimal. Procedures to estimate $G_{\alpha\beta,\gamma\delta}$ from triplet correlations are also being investigated.

An atlas of 164 simple patterns has been hand computed, and provides material for a number of mathematical theorems on patterns which are uniquely specified (up to trivial deformations) by their pair counts.

3. Digital Tracking

Results on the digital tracking of 141 tracks (largely in pictures of poor quality) are now known. A number of test scores (e.g., percentage of track successfully tracked, number of gaps seen, left-right shifting asymmetry, etc.) have been computed and the correlation matrix found. Results are very disappointing: in all but 20% of the cases, tracking is terminated in the first 8 steps because of an extensive number of gaps, requests for multi-tracking, or the presence of a glob.

4. Equipment

The purchase order for the basic high resolution CRT system has been released to the Digital Equipment Corporation, Maynard, Massachusetts. Photo detection and optical equipment will be fabricated here.

(K. Dickman, K. Hillstrom, M. Kuchnir,
B. H. McCormick, F. Shimamoto and J. N. Snyder)

PART V

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of April, two new routines were added to the Illiac Library.

M 34 - 318   Symmetric Matrix Inversion (Entire Program). This routine inputs a symmetric matrix as a lower triangular matrix, and inverts it. Input may be from tape or from the drum. Output may be stored on the drum as a lower triangular matrix, or punched to "d" decimal places ($1 \leq d \leq 12$) as a square matrix, a lower triangular matrix, or a column of the diagonal entries.

(F. Shimamoto)

KSL 5.14 - 319   Symmetric Matrix Inversion (Closed Subroutine). This routine has essentially the same properties as the routine M 34 - 318 described above, except that it is written as a closed subroutine which can be incorporated in other programs.

(F. Shimamoto)

Illiac Usage

During the month of April, specifications were presented for 29 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 1915T. Numbers followed by T are for theses.

1915T   Agronomy. Dual Purpose Corn Culture. This is a study of nine planting systems and three dates of removal of green forage from a field of grain corn, to obtain a maximum total production of grain plus forage from an acre of land. Systems were designed to study the ecological influence of including extra plants for forage in a grain crop and also to determine the

practicability of using machinery for harvesting this. Under every planting system used, 16,000 plants were left eventually, after removing green soiling crop at different stages of growth, to yield grain. The three dates of harvesting were 15 days before tasseling, at tasseling, and 15 days after tasseling. The experiment was conducted at two locations to sample climatic variations.

The Illiac will be used to perform analyses of variance for evaluation of the treatment combinations used. The design is a split block randomized complete block.

1916T Education. Analysis of Component Learning Curves. Three discrimination learning tasks have been given to two groups. Task one uses perfect validity, task two probabilistic validity, and task three is a combination of tasks one and two. In each case, the subject must learn to maximize the number of correct discriminations.

The learning curves obtained under these conditions will be analyzed assuming a general form

$$X = \sum_{n=1}^{n} A_{nm} B_{mN}$$

where $\underline{X}$ is an $\underline{n} \times \underline{N}$ matrix of scores (n - trials, N persons)

A_{nm} a matrix of trial parameters

B_{mN} a matrix of individual parameters.

A least squares estimate of X is sought using the $\underline{r}$ largest eigenvalues of XX',
i. e.,

$$\hat{X}_r = U_r \Gamma_r W_r$$

Finally $\hat{X}_r$ will be obtained.

$$\hat{X}_r = B_r Z_r, \text{ where } B_r = (N)^{-1/2} U_r \Gamma_r$$

$$Z_r = N \Gamma^{-2} B_r' X.$$

Essentially, the method considers the observed score matrix as being approximated in the least squares sense by the sum of a number of orthogonal components, each of which is based upon one of the $\underline{r}$ largest roots. Each orthogonal component can be further analyzed into the product of two matrices the first of which is

analogous to factor loadings (trial parameters) on the rth vector. A plot of these over trials gives a component learning curve. The second matrix can be considered individual parameters over r component curves. The extent to which various individual parameters promote learning on a second learning task will be determined.

1917 Chemistry. Distribution of Distances. The distribution of squared end-to-end distances in high polymers is of great interest. This program determines the distribution of squared end-to-end distances in samples of non-self intersecting random walks previously generated on the Illiac as part of a continuing study of the properties of this model of high polymer systems.

The program itself is quite straightforward. Information concerning the squared end-to-end distance of each polymer is computed as the polymer is read into the computer. This information is stored in 2700 counters contained in 675 locations in the Williams Memory. Final punching is so arranged that actual punching is essentially limited to non-zero counters in such a way that the output format when printed is clear and readable and yet punching time is minimized.

1918T Sociology. Inmate Perception. The problem is to ascertain differences in the perception that prison inmates have of certain correctional officials, family members, and themselves. A semantic differential was utilized to obtain these perceptions, and it is hoped that Illiac routine KSL 2:70 can be utilized to obtain scores representing the degree of disparity between the perception of certain select roles. The problem has a sample size of 262 inmates who are asked to describe nine concepts on 22 variables.

1919T Agricultural Economics. Analysis of Income on Irish Farms. Regression problems on Irish farms will be considered in order to develop marginal value products for enterprises and inputs.

Linear programming on special case study forms will be used. In all, approximately 1,000 farm records are involved.

1920 Animal Science. Minimizing Excess Amino Acids in Swine Rations. The method of linear programming will be used to determine the possibility of meeting certain protein and amino acid contents of swine rations. About 14 requirements will be considered, with 28 ingredients.

1921 Mechanical Engineering. Annular Nozzle Design. It is intended to develop a program for the Illiac to calculate the profile of an annular nozzle producing uniform supersonic flow at the specified mach number. This calculation will be based on the "method of characteristics". Although some routines developed previously will be readily adaptable, other special routines have to be developed to calculate the flow field within the nozzle by iterative, step by step procedure.

1922 Natural History Survey. Reproductive Physiology in the Raccoon. This problem is concerned with reproductive physiology and related phenomena in the raccoon. Organ weights from various age groups and both sexes will be taken from several months and several years. Tests will be run to determine if such factors as age, sex, population density, disease, previous breeding history, time of year and perhaps other factors increase the stress in the raccoon as reflected by adrenal weights. Also, an attempt will be made to learn if gonad weights fluctuate from month to month and from season to season, perhaps influenced by different environmental and other factors. The Illiac will be used to determine analysis of variance for many of these factors.

1923 Psychology. Cognitive Characteristics of Individuals in Two Cultures. The response of individuals in two cultures, toward a set of stimuli, are to be analyzed using certain exploratous techniques. The study is exploratory--a matter of finding out if the suggested techniques work with a particular kind of data.

The first problem involves a matrix (Y) of numbers (measures on a social distance scale of the responses of individuals to stimuli). This matrix Y is to be used with KSL 5.02 to get YY' and then the characteristic roots and vectors of YY' will be required (using M-22).

The second problem tests a "prediction equation" or "congruity equation". A stimulus 1 is judged on a scale and a measure e_1 is obtained, where e can vary between -3 and +3, and stimulus 2 gives a measure e_2, etc. When all stimuli are presented simultaneously, then the formula is supposed to predict a person's response to the compound stimulus. In this case, there are four stimuli, and a compound stimulus consisting of four elements and the prediction equation is:

$$e \text{ predicted} = \frac{|e_1| e_1}{\sum_{i=1}^{4} |e_i|} + \frac{|e_2| e_2}{\sum_{i=1}^{4} |e_i|} + \frac{|e_3| e_3}{\sum_{i=1}^{4} |e_i|} + \frac{|e_y| e_y}{\sum_{i=1}^{4} |e_i|}$$

The data are responses of 25 Greeks and 25 Americans (who have certain interesting characteristics and are drawn from a larger group of persons) to 8 simple and 6 compound stimuli, on 16 different scales. Following computation of the "contiguity equation" correlations of the predicted and the obtained scores are needed.

1924 Psychology. Structure of Vocational Motivation. This is to be a study of the dynamic interrelationships between vocational choice and motivational components, with the emphasis on structural components of motivation. The primary objective is development of a measuring device for vocational motivation based on an item analysis of items in the present data that are found to be highly correlated with the resultant factor structure. The study will include an examination of the relationship between results obtained through utilization of alternative factorization procedures, and an attempt will be made to develop a measuring device for vocational motivation which will yield the optimum significance that present data permits.

1925T Physics. Helium Polarization of Neutrons. The research problem is to determine the polarization of neutrons from deuterium photodisintegration. The neutron polarization is determined by scattering of neutrons by helium. This Illiac code is to determine both the He(n,n) differential cross-section and the neutron polarization as a function of neutron energy. Two sets of phase shifts will be input to the computer and the polarization and differential cross-section will both be calculated as function of neutron angle and energy. The cross-section will be used to decide upon choice of phase-shifts and the polarization curves will be used later in determining the deuterium polarization.

1926 Institute for Research on Exceptional Children. The Frustration-Aggression Relationship in Parents of Severely Retarded Children. It is hypothesized that a relationship exists between frustration and aggression in the parents of severely retarded children. The birth of a severely retarded

child is taken as the original source of frustration with the degree of resultant aggression positively correlated with the increasing aspect of the etiology of the retardation.

Data are ratings on 18 parental responses and characteristics from 604 parents. These responses and characteristics have been classified as sources of frustration; acts of aggression; escape; etc. In order to demonstrate the hypothesis empirically certain intercorrelations must exist. In addition, factors with specific variables in their loadings must be extracted.

1927 Theoretical and Applied Mechanics. Analysis of Simple Self-Aligning Dynamical System. The problem is an analysis of a spring-mass system of forced vibrations, taking into account non-linearities and the three common forms of damping (hysteresis, coulomb, and viscous). The mass of the system is eccentric and rotates about the geometric center of the body with a constant angular velocity. It is the motion of the center of mass, or the degree of alignment of the center of mass, and not the motion of the geometric center of the body that is to be investigated.

The computer will be used to evaluate the complex algebraic equations that arise in the analysis. The parameters will be supplied.

1928 Psychology. Factor Analysis of Adult Personality Traits. One-hundred eighty adult subjects have been tested on a total of 270 personality variables. After complete intercorrelation of a subset of 60 of these variables, a factor analysis will be carried out; the factor structure of the remaining 210 variables will be computed by means of Dwyer's extension analysis, thus getting the projections of these 210 variables on the factors extracted in the subset of 60 variables. Oblique factor rotations will be used in this research.

This particular study is the latest in a series of researches that aimed at a cross-validation of previous results in the field of objective personality test factors.

1929 Mathematics. Sequential Test of Poisson Parameter. It has been shown the Sequential Probability Ratio Test, for testing $H_1:\theta$ large versus $H_0:\theta$ small subject to levels of error α_0 at θ_0 and α_1 at θ_1, uniformly minimizes the expected number of observations required for θ outside the open interval (θ_0,θ_1). Hence, it is a very desirable test when θ_0 and θ_1 are close. Given parallel lines in the plane $y_1 = cx + d_1$ and $y_0 = cx + d_0$ the test is to continue taking observations z_i, if

$$cx + d_0 < \sum_{i=1}^{x} z_i < cx + d_1,\ x = 1, 2, \ldots,\ d_1 > d_0$$

with the rules stop and accept H_0 if the left hand inequality is violated, stop and accept H_1 if the right hand inequality is violated.

The levels α_0 and α_1 and expected number of observations EX can be found by multiplying probabilities on points by the probabilities of jumping to higher points and probabilities of jumping across boundaries.

A table of α_0, α_1, and EX for the Poisson Distribution for various slopes and intercepts of the boundaries y_0 and y_1 will be made.

1930 Electrical Engineering. Direction Finder. Data taken from a radio direction finder should approximate a $\frac{\sin x}{x}$ curve. A preliminary examination will be made of this data in order to find the most significant n points, the center of gravity using only the n points, the polynomial of degree n-1 to fit the n points, and a fit of the form $\frac{a \sin bx}{bx}$ by the method of least squares.

1931T Theoretical and Applied Mechanics. Solution of an Elastostatics Problem in a Multiply Connected Region. It is desired to determine the stress field in a plane triply connected region where one of the boundaries experiences a hydrostatic load. To this end the problem was formulated in terms of two arbitrary analytic functions of a complex variable following the methods of Kolossoff and Muskhlishvili. In this representation any two analytic functions for this problem satisfy conditions of equilibrium and compatibility, thus leaving only the boundary conditions to use in selecting the appropriate analytic functions to yield the unique stress field in question. By means of an extension of the Laurent expansion, suitable series representations of the two analytic functions in the region occupied

by the body were obtained. Each function is represented by the sum of three infinite series of the complex variable and have undetermined complex coefficients. From the relations of the stresses to these analytic functions, boundary conditions have been obtained as functional relations on the boundaries of the two functions. Substitution of the series representations into the boundary conditions yields an infinite system of linear equations in the undetermined coefficients. Illiac will be used to solve this system approximately by solving the resulting equations after two truncations. The first truncation will result in a system of order 132 and the second a system of order 96. The two truncations are necessary in order to attain some insight as to the convergence of the system.

1932T Agricultural Economics. Effect of Land Size on Farm Costs and Income. Multiple linear and curvilinear regressions and regression methods applicable to production function analysis will be used to establish the effect of changing land size upon farm incomes and various production costs. The results of this project should be especially applicable to questions of land valuation in land acquisitions for highway construction.

1933 Chemistry and Chemical Engineering. Reaction Kinetics. The chemical kinetics of the system of reactions

$$\sum_{j=1}^{m} a_{ij} A_j \longrightarrow 0 \qquad i = 1, 2, \ldots, n$$

is described by the following set of non-linear first-order differential equations:

$$\frac{dc_j}{dt} = -\sum_{i=1}^{n} k_i a_{ij} \prod_{\ell=1}^{m} c_\ell^{\gamma_{i\ell}} \qquad j = 1, 2, \ldots, m$$

The purpose of this problem is to integrate this system of equations to obtain $c_j(t)$ and other related quantities of interest to the interpretation of experimental data. The mathematical method to be used is the Runge-Kutta-Gill integration procedure.

1934T Electrical Engineering. Determination of Probability Density by Monte Carlo Method. The behavior of a system under noisy input condition can be described by a set of difference equations

$$u_{n+1} = g(u_n, \nu_n, \psi_n, \psi_{n+1})$$

$$\nu_{n+1} = h(u_n, \nu_n, \psi_n, \psi_{n+1})$$

where u and ν are system variables and ψ is the noise component. The problem is to find the probability density $p(u_n \nu_n)$ for large n. The Monte Carlo method is quite suitable to solve the problem. V9 will be used to generate an arbitrary initial condition $u_0 \nu_0 \psi_0$. By means of the equations u_n and ν_n are solved iteratively. For a preassigned value of n (say 500) the value of u_n and ν_n is recorded. The same procedure is repeated m times (say m = 5000). Then the distribution of $u_n \nu_n$ is the approximate $p(u_n \nu_n)$ required.

1935 Theoretical and Applied Mechanics. Carriage Dynamics Study. The problem is an investigation of the effect of structural flexibility on the initial motion of an artillery shell and the effects of this flexibility on the stability of the structure during the period which the shell is in the barrel.

The mathematical problem consists of the solution of a system of seven second order ordinary differential equations subject to a prescribed set of initial conditions.

1936T Theoretical and Applied Mechanics. Conical Shell. This is an investigation on the deflections of a thin conical shell neglecting shear deformation and symmetrically loaded. Writing down the strain energy expression and employing the theorem of minimum potential ultimately one obtains four Euler equations. Applying these to a shell broken into 26 equal parts, one arrives at 58 simultaneous linear algebraic equations. A solution of these equations yields the deflections at each panel point.

1937T Sociology. Student-Student Relations and Interactions. The purpose of this problem is to analyze the effectiveness of instructional television when used in conjunction with undergraduates who are leading

discussion sections. The question is: can these untrained students effectively and efficiently lead educationally productive discussions in Sociology 105.

KSL - K8 would be used to calculate r's, the r's between sets of semantic differentials and other pertinent variables (age, sex, grade point average, etc.); these results will then be factor analyzed to obtain either oblique or orthogonal factors, according to which procedure seems more validly useful on the basis of the r's obtained.

1938 Physics. Solution of Quartic Equations. Linear combination of atomic orbital wave functions are being constructed for the ground state of the F-center in alkali-halides by fitting paramagnetic resonance data. The parameters of interest appear as the roots of a quartic equation.

1939 State Water Survey. Rainfall Homogeneity Analysis. The Illinois State Water Survey has operated a raingage network of 49 gages located on a grid pattern within a 400 square mile area for a period of six years. A homogeneity study of the rainfall within the network area is to be made. It is planned to determine variances and compute necessary quantities for an analysis of variance table.

The analysis is intended for a search for significant differences between rows and columns of rainfall measurements on the network for months of each year, for all months over each year, all months over all years. Periods of time other than months may also be studied, depending upon results of the monthly study.

1940T Special Education. Effect of School Achievement on Parent's and Child's Attitudes. One-hundred fifty monthers and 150 children have taken a test. The mother's test of child-rearing attitude has 50 items; the children's test of attitude toward themselves has 28 items. Each test has about ten factors. The problem is to find the effect of school achievement on parent and child.

1941 Physical Education. Computation of Standard Scores by Columns. The problem is a simple one of computing standard score tables for use in the assessment of individual profiles concerning human fitness data.

A standard library routine (KSL 4.1) is to be used in order to provide standard scores by columns.

1942T Agronomy. Dwarf Corn. This is a problem comparing normal inbred crosses with dwarf-normal inbred crosses. There are 28 hybrids in all split into three main groups; group one are all normal, group two are all normal-dwarf, and group three are all dwarf.

This will be analyzed as a split plot design and analysis of variance used to compare the normal to the dwarf-normal crosses.

1943 Theoretical and Applied Mechanics. Location of Elastic-Plastic Boundary. In the formation of the "plastic hinge" in a wedge the elastic-plastic boundary has been assumed to be circular.

Recent investigations of the octahedral shearing stress indicates this may be a false assumption.

By computing the value of the maximum octahedral shear stress at the boundary, and then substituting a percentage of this value, say 80 per cent, two points on the boundary are located on the elastic-plastic boundary. If the radius is now swung from θ to zero, two values of r will be obtained for each value of α. This will sweep out the elastic-plastic boundary. r and α are the polar coordinates within the wedge; θ is the half-angle of the wedge.

The equation to be solved for r is:

$$(D^2-A^2\sin^2\theta)r^4 + (ABm \sin\theta \sin 2\theta)r^2 + B^2m^2\left[\frac{3}{4}(\cos 2\theta - \cos 2\alpha)^2 - \sin^2 2\theta\right] = 0$$

where:

$$A = \frac{2}{2\alpha-\sin 2\alpha}$$

$$B = \frac{2}{\sin 2\alpha - 2\alpha\cos 2\alpha}$$

$$D = \frac{9}{2}K^2\tau_G^2$$

Table I shows the distribution of Illiac machine time for the month of April.

TABLE I

	Hrs:Min	
Scheduled Maintenance	50:24	
Unscheduled Maintenance	17:35	
Drum Engineering	2:58	
Leapfrog	5:28	
Library Development	1:26	
Classes	20:11	
Instruction	:13	
Demonstrations	1:08	
		99:23

Use by Departments

Agricultural Economics	12:52
Agricultural Engineering	:40
Agronomy (0015-15-306)	1:43
Agronomy	6:51
Animal Science	1:19
Astronomy (NSF-G-14834)	:17
Bureau of Community Planning (84 16 383)	:53
Bureau of Educational Research	:55
Chemistry (NSFG 7336)	5:27
Chemistry (NSFG 5907)	6:12
Chemistry	34:33
Civil Engineering (NSF-G 6572)	1:16
Civil Engineering (AASHO ROAD TEST)	3:06
Civil Engineering	66:01
College of Medicine (NIMH-USPH M-637)	8:35
Coordinated Science Lab. (DA-36-039-SC56695)	47:43
Digital Computer Laboratory (NONR-1834(27))	:18
Digital Computer Laboratory (NSF GRANT 9503)	20:35
Economics (NSFG 7056)	5:29
Economics	:07
Education	:08
Electrical Engineering (NASA-NSG 24-59)	1:20
Electrical Engineering (NSFG 7421)	:50
Electrical Engineering (NOBSR 64723)	:24
Electrical Engineering (NONR 1834(02))	7:54
Electrical Engineering (AF 7043)	1:30
Electrical Engineering	12:10
Finance (IHR-71)	1:25
Geological Survey	:12
Institute of Communications Research (44-28-20-378)	3:26
Institute of Communications Research (USPHM-3941)	3:56
Institute of Communications Research	:26

Institute of Labor and Industrial Relations	1:39		
Inst. for Res. on Excep. Children (HE and WSAE 8204)	4:24		
Institute for Research on Exceptional Children	:12		
Mathematics	10:14		
Mechanical Engineering (NSG-13-59)	:04		
Mechanical Engineering	6:08		
Petroleum Engineering	:05		
Physics (NONR 1834(05)A)	7:06		
Physics (NONR 1834(12))	:17		
Physics (Gen. Elec. Fellowship)	:54		
Physics	7:27		
Psychology (AF 49(638) 371)	:45		
Psychology (1715)	3:04		
Psychology (ONR-46-32-66-362)	3:32		
Psychology	52:37		
Sociology	2:12		
State Water Survey (DA-36-039-SC75055)	6:57		
State Water Survey	3:16		
Theoretical and Applied Mechanics (DA-11-070-508)	6:37		
Theoretical and Applied Mechanics	4:16		
Veterinary Physiology	:10		
Williams College	2:16		
		382:45	
			482:08

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table.

Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Punch	1
Control	1
Drum	10
Power Supplies	3
Scope	1
Unknown	3
Total	19

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/3/61	21:45	:00	2:15	0		:00	:05	0
4/4/61	21:58	:00	2:02	0		:00	:15	0
4/5/61	21:29	:29	2:10	2	(1) Punch #5 out of adjustment. (2) Drum failure.	:00	:53	0
4/6/61	15:36	5:44	2:40	2	(1) Drum failure. (2) Drum failure.	:00	:00	0
4/7/61	21:57	:05	1:58	1	(1) Drum failure.			
4/10/61	18:26	4:17	1:17	2	(1) Drum failure. (2) Drum failure.	:00	:10	0
4/11/61	20:15	:56	2:49	2	(1) Unknown. (2) 2000 v power supply erratic.	:00	:00	0
4/12/61	19:21	1:05	3:34	1	(1) Control error in Illiac.	:00	:01	0
4/13/61	20:06	:22	3:32	1	(1) 200 v power supply unstable.	:00	:00	0
4/14/61	21:49	:00	2:11	0		:00	:23	0
4/17/61	21:39	:15	2:06	1	(1) Illiac went off, reason unknown.	:00	:26	0
4/18/61	20:59	:00	3:01			:00	:42	0
4/19/61	20:23	:05	3:32	1	(1) Unknown.	:00	:00	0
4/20/61	19:29	2:01	2:30	2	(1) 3000 volt power supply. (2) Drum failure.	:00	:11	0
4/21/61	21:53	:00	2:07	0		:00	:09	0
4/24/61	21:49	:00	2:11	0		:00	:02	0
4/25/61	20:10	1:00	2:50	1	(1) Scope output trouble.	:00	:04	0
4/26/61	20:22	:28	3:10	1	(1) Drum failure.	:00	:20	0
4/27/61	21:23	:00	2:37	0		:00	:03	0
4/28/61	20:57	1:05	1:58	2	(1) Drum failure. (2) Drum failure.	:00	:11	0
TOTALS	411:38	17:52	50:30	19		:00	3:55	0

PART VI

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New 650 Codes

During the month of April, no new routines were added to the Digital Computer Laboratory 650 Library.

International Business Machines 650 Usage

During the month of April, specifications were presented for 13 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 234'T. Numbers followed by T are for theses.

234'T Theoretical and Applied Mechanics. Moment-Curvature Relationship for Columns. A column is subjected to axial and lateral loads. In order to determine the stresses and deflection of the column, it is necessary to have curves relating load, moment and curvature. The IBM 650 will be used to calculate points so that these curves may be drawn.

235' Electrical Engineering. Position Calculation for the Sun. The problem is to determine the positions (azimuth and elevation) of the sun (at a certain time of a day) from given "hour angles" and "declination". The mathematical expressions used are:

$$\left.\begin{aligned} \sin h &= \sin\phi\,\sin\delta + \cos\phi\,\cos\delta\,\cos t \\ \cot A &= -\frac{\cos\phi\,\tan\delta}{\sin t} + \sin\phi\,\cot t \\ a &= A + 180^{\circ} \end{aligned}\right\} \quad \begin{array}{ll} \text{Given} & \phi \text{ (latitude)} \\ & t \text{ (hr angle)} \\ & \delta \text{ (declination)} \\ \text{Find} & a \text{ (azimuth)} \\ & h \text{ (elevation)} \end{array}$$

Approximately 120 points are required for each run (or a maximum of 15 minutes machine time per run). The data is to be used on the 28 foot diameter parabolic antenna for pointing accuracy calibration using the sun as a reference.

236'T Chemistry. Stability Constants. This research problem consists mainly of determining and correlating formation constants (K_1, K_2, K_3) of various substituted β-diketone-, and β-ketoiminelanthanon (III) complexes. K_1, K_2, K_3 are respectively for the equilibria

$$M^{+3} + Ch^{-} \longrightarrow MCh^{+2},$$

$$MCh^{+2} + Ch^{-} \longrightarrow M(Ch)_2^{+}$$

$$M(Ch)_2 + Ch \longrightarrow M(Ch)_3.$$

The method used in calculating values is the simple algebraic solution of a system of three equations with three unknowns starting with the general equation

$$\bar{n} = \frac{\sum_{1}^{n} n\, K_n A^n}{\sum_{1}^{n} K_n A^n}$$

In this case various $\bar{n}$ are determined experimentally and K_n are calculated.

237' Agronomy. Soil Moisture Flow with Source Term. The problem involves the solution of the non-linear differential equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x} \left(D(\theta) \frac{\partial \theta}{\partial x}\right) + S$$

where θ is water content, x is distance, t is time, D(θ) is diffusivity and S is the source term. The case in which there was no source term has already been solved. This solution required the computation of about 25 derivatives about initial values from which the computation was made using a Taylors series expansion. If the solution diverged new values were taken from the last reliable data computed and the entire process repeated. At present, only those D and S functions which allow linearization of the equation can be handled.

The computation of the 25 derivatives as well as the evaluation of the Taylors series is very tedious. Since many computations are repetitious of earlier ones, machine computations are ideally suited for this type of a problem.

238' Psychology. Simplex Theory. Calculation of means, variances, standard deviations and intercorrelations between variables (college grades) will be made in order to test the simplex hypothesis of the predictive value of grades by high school rank.

239'T Agricultural Economics. Programming Farm Production and Financial Decisions. A standard linear programming use is to develop optimal production plans for a farm. Capital inputs are aggregated into a single equation, and details of financial management are not considered. The purpose of this problem is to investigate interrelationships between production and financial planning when borrowing funds is an alternative. A second purpose is to study effects of seasonal patterns of expenditures on optimal organization. Finally, effects of several patterns of lender restraint are to be explored.

Programming is used to maximize farm profits in linear equation form subject to a set of linear constraints. The constraints are restraints on financial and production alternatives due to the short run nature of the planning horizon.

240' Civil Engineering. Ultimate Strength Approach to Flexible Pavement Design. The nature of this problem is to determine the ultimate strength of a layered flexible pavement by solution of a logarithmic spiral shear failure curve. The main approach to the solution is by equating the load moment to the sum of the weight moment and the cohesion moment.

241' Navy Pier. Illinois University Cooperative American College Testing Research. The correlations for which computer time is required involve the inter-relationships among a large battery of test scores, including the tests of the American College Testing Program and the College Entrance Examination Board. Measures of high school background and college success are also included. Correlations are to be calculated for a number of sub-groups of students (lowest quarter in high school class, students taking a particular mathematics test, etc.).

The correlations are part of a large scale research program sponsored by the University of Illinois, in cooperation with the other five state universities in Illinois (working through a committee of the

Joint Council on Higher Education), and the American College Testing organization. The results of the study will be made available to the six participating universities and will presumably also be published for general circulation in professional circles.

242'T Marketing. Retail Trade in Standard Metropolitan Areas. The problem under consideration is to compare the central cities of standard metropolitan areas in the United States to the suburbs of these standard metropolitan areas in terms of the adjustment made by retail trade to selected market factors. The hypothesis under consideration is that retail trade, measured by the number of stores and sales, has made a discernible adjustment to changes in population, income, employment, service trades and wholesaling during the period from 1939-1960.

The 650 will be used to compare stores and sales in retail trade to the above mentioned market factors. Calculations will be made of the distribution of each variable between the central city and the suburbs. Calculations will be made of the growth of each variable in central cities and suburbs over time. Finally, average distribution and growth will be determined as a basis for grouping the other changes in the standard metropolitan areas.

243' Physics. Reactor Kinetics: Integral Equation. An integral equation approach to the solution of the reactor kinetics equations has been developed. This approach offers several advantages over a direct numerical integration of the differential equations, among which are increased stability (since the kinetics equations involve large time constants) and speed.

It is now necessary to compare a number of different numerical quadrature methods to optimize a general digital computer program which is being developed. It is planned to test the quadrature methods by programming suitable subroutines in the Bell Laboratories interpretive system, to allow frequent changes without reassembly. Since the interest in these calculations is in the comparison of methods rather than in the writing of a production code, the loss in machine time due to using the standard Bell system should be compensated by the ease of use and elimination of assembly time.

Specifically, the integral equation approach leads to the following computational procedure: given $n(x')$, $I_i(x')$, $x' \leqq x$, calculate

$$n(x+\Delta x) = F(x+\Delta x) + \sum_i b_i \left\{ e^{-m_i \Delta x} I_i(x) + e^{-m_i(x+\Delta x)} \int_x^{x+\Delta x} k(x')n(x')e^{m_i x'} dx' \right\}$$

To proceed for $x+2\Delta x$, one then needs

$$I_i(x+\Delta x) = e^{-m_i \Delta x} I_i(x) + e^{-m_i(x+\Delta x)} \int_x^{x+\Delta x} e^{m_i x'} \beta(x')n(x')dx'$$

Various methods of approximating the integrals together with the corresponding effects on stability and maximum step size are to be investigated here.

244' Mining and Metallurgical Engineering. The problem is essentially one of determining if the mathematical model of diffusionless phase transformations gives results equal to or in accord with the experimental results. The part of this problem to be done on the computer is to determine one of the macroscopic results of the transformation, namely the magnitude of the shear. The shear can be determined by evaluating

$$\frac{(\vec{q}_1 - \vec{q}_2) \times (\vec{p}_1 - \vec{p}_2)}{(\vec{q}_1 - \vec{q}_2) \cdot (\vec{p}_1 + \vec{p}_2)} = \tan \frac{\theta}{2} \quad a_0$$

$$\phi_{ij} = \delta_{ij} \cos \theta + a_i a_j (1-\cos \theta) - \epsilon_{ijk} a_k \sin \theta$$

where $\vec{q}_1 + \vec{p}_1$ are two-initial unit vectors in the interface plane and $\vec{q}_2 + \vec{p}_2$ are the resultant unit vectors after the phase transformation.

245' Chemistry. Variation Orbitals. Using previous programs atomic core potentials of the form

$$V = \frac{A + Be^{-\gamma r}}{r} \qquad \text{(A, B, } \gamma \text{ constants; r radial distance)}$$

have been worked out for transition-metal ions and atoms. It is now desired to see whether, using this potential and applying a straightforward variation treatment, one can obtain good, approximate radial wave functions

of the form $r^m(e^{-\alpha r} + be^{-\beta r})$. The problem has been reduced analytically to the point where the machine computation involves only finding the minimum of an algebraic function with respect to three parameters. Results will be compared with the numerical integrations previously done. If agreement is good, an "empirical" prescription for 3d functions can be given for use where Slater functions are now used in approximate calculations.

246' Statistical Service Unit. Instructor Evaluation. The computer will be used to determine the validity of individual evaluations as rated by small groups of one to thirty persons. The group ratings of approximately 2,000 different individuals will be computed and the results tabulated by the individual's field of major interest. The results will be used to develop a more accurate and complete method for future evaluations.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of April.

TABLE I'

		Hrs:Min	
Scheduled Engineering		15:55	
Unscheduled Engineering		27:12	
Air Conditioning		:52	
Digital Computer Lab Library		12:08	
Classes		39:42	
CE 391	8:56		
MATH 295	7:03		
MATH 395	23:28		
Instruction	:15		
Demonstrations		2:28	
Wasted		4:52	
			103:09

Use by Departments

		Hrs:Min		
Agricultural Economics		11:05		
Agronomy		7:13		
Animal Science		5:53		
Astronomy		2:39		
Chemistry		12:13		
Civil Engineering		20:39		
Digital Computer Laboratory		3:04		
Electrical Engineering		:56		
Graduate College		3:22		
Horticulture		:15		
Mechanical Engineering		4:51		
Mining and Metallurgical Engineering		2:46		
Physics		6:40		
Small Homes Council		:29		
Sociology		1:04		
State Water Survey		7:12		
Statistical Service Unit		119:06		
Agricultural Economics	:15			
Agricultural Extension	1:21			
Bureau of Educational Research	2:23			
Bureau of Institutional Research	8:01			
Bursar's Office	7:42			
Business Office	17:35			
Civil Engineering	:24			
Dairy Science	:38			
DHIA	32:30			
Economics	:06			
Education	25:47			
Marketing	3:10			
Navy Pier	10:50			
Psychology	2:56			
Statistical Service Unit	4:54			
Student Counseling	:34			
Theoretical and Applied Mechanics		2:51		
			212:18	
				315:27

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 11:30 p.m. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for April.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

727 and 652 Tape units and tape control		7
Unit fails to unload properly	1	
Unit fails to rewind properly	3	
Unit fails to read	1	
Unit damages tape	1	
Unit writes incorrectly	1	
650 console and magnetic drum unit		14
Distributor	10	
Program register	3	
Drum	1	
533 card-read punch		6
Reads incorrectly	3	
Card jam	1	
Destroyed card	1	
Continues to cycle on read side	1	
407 accounting machine		7
Prints incorrectly	4	
Spacing when should not	3	
Total		34

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPE OF FAILURE CAUSING STOP
4/3/61	4:27		11:10	:05	0		Repair time is for the distributor trouble on 3/31. It continued on 4/3.
4/4/61	14:38		(:30)*	1:02	1		(1) Tape unit 3 did not unload properly.
4/5/61	15:04		:34	:32	3		(1) Distributor will not clear to 0. (2) Tape unit 2 damaged tape due to pinch roller being too tight. (3) Position 9 of distributor has errors.
4/6/61	15:49			:09	3		(1) 533 incorrectly read word four. (2) Blank bit in distributor. (3) 407 printed a - sign when there should not have been any sign printed.
4/7/61	15:13			:25	2		(1) Blank bit in pos. 7 of distributor. (2) Random + and - signs in words 3 and 4 on 407.
4/10/61	11:23	4:12	:02	:09	2		(1) Word 1 on the 407 prints at random a + sign. (2) Multiple bits in distributor.
4/11/61	16:19			:13	3		(1) Position 7 of program register has missing bits. (2) Tape unit 2 did a complete rewind at full speed. (3) Pos. 2 of distributor blank.
4/12/61	14:31		:09	:12	2	:52	(1) Tape unit 2 would not read. (2) Card jam in 533.
4/13/61	11:02		4:21	:11	2		(1) Position 9 of distributor had blank or multiple bits. (2) Drum blanked out in positions 0006-0008.
4/14/61	11:41		3:47	:03	1		(1) Alpha information in words 1, 2, 3, 4 read incorrectly about 70 times.
4/17/61	8:07	7:23			1		(1) Last quinary bit in position one of distributor.
4/18/61	11:18		4:28		0		Engineering time was spent on 407. Found a circuit breaker timed improperly.
4/19/61	14:59			:41	2		(1) Tape unit did not rewind at the end of the job. (2) 407 spacing when it shouldn't.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPE OF FAILURE CAUSING STOP
4/20/61	13:15		2:00	:20	4		(1) Program register had multiple bits. (2) Distributor had multiple bits. (3) Print wheel 22 on 407 prints incorrectly at random. (4) 407 spaced when it should not have done so.
4/21/61	15:41			:06	2		(1) Pos. 9 of distributor had multiple bits and accumulators were blank. (2) 533 read destroyed a card.
4/24/61	11:13	4:10		:02	1		(1) 533 read a card incorrectly.
4/25/61	15:09		:21	:05	1		(1) 533 read continued to cycle.
4/26/61	15:30		:20	:06	3		(1) 407 spacing when should not do so. (2) Tape unit 1 writes incorrectly. (3) Tape unit 1 fills vacuum tube with tape.
4/27/61	15:52			:12	1		(1) Program register picked up an extra bit in pos. 2.
TOTALS	266:59	15:45	27:12	4:59	34	:52	

PART VII

GENERAL LABORATORY INFORMATION

Seminars

"Aspects of Storage Control in the Genie Automatic Coding System", Dr. John K. Iliffe, Rice University, Houston, Texas, April 3, 1961.

"Dynamic Programming and Digital Computers", by Dr. Richard Bellman, RAND Corporation, Santa Monica, California, April 10, 1961.

"Considerations in the Development of a Compiler for the SILLIAC Computer", by Dr. B. A. Chartres, Adolph Basser Computing Laboratory, University of Sydney, Australia, April 21, 1961.

"Compilers and Automatic Executive Systems", by Professor Bernard A. Galler, University of Michigan, Ann Arbor, Michigan, April 24, 1961.

Reports

Report No. 108, "Notes on John von Neumann's Cellular Self-Reproducing Automaton", by Dr. Arthur W. Burks, April 24, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	10	1	10.75
Visiting Faculty	0	0	-
Research Associates	3	0	3.00
Graduate Research Assistants	9	25	22.75
Graduate Teaching Assistants	0	5	2.00
Administrative and Clerical	7	1	7.33
Other Nonacademic Personnel	40	15	45.33
Other	69	47	91.16

The Laboratory Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbaum, J. E. Robertson, and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

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May, 1961

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PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Physical Aspects of Machine Construction

1.1 Chassis Frames

The completed frames for the first order have arrived and are in use.

The orders for the second group of chassis frames have been written and the casting order is complete. These orders consist of 16 (12 x 24), 52 (12 x 18), 2 (12 x 12), 8 (8 x 18) and 22 (8 x 12) chassis frames.

(C. E. Carter, T. E. Kerkering)

1.2 Air Conditioning

The input air ducts into the machine are in place. The changes necessary for the mounting of the exhaust duct have been done and the ducts are being fabricated.

The platform for mounting the air-handling units is complete and preparation for their mounting is going on.

(Lee Whyte and Physical Plant)

1.3 Flow-Gating

A test rack for flow-gating chassis was completed and 7 of 12 male chassis were tested for machine usage.

The positioning of the flow-gating center wall was completed.

(H. Guckel, S. P. Krabbe)

1.4 End Connections

Communicating lead length and changes due to the new cable drivers were studied. Corrections in the placement of part of the end connections were made.

(S. P. Krabbe, H. E. Lopeman, J. O. Penhollow)

1.5 Delayed Control

A final component count for delayed control was completed. This count included the new cable driver circuits.

(H. E. Lopeman, R. E. Swartwout)

1.6 Shop Progress

	MAU	Flow-Gating	1/2 Core
Complete	32 Chassis	24 Chassis	19 Chassis
Lacking Male Frames	10 Chassis		3 Chassis
Awaiting Diodes and Inspection	3 Chassis		6 Chassis
In Wiring Stage	2 Chassis		5 Chassis
Held due to Parts Shortage	1 Chassis	2 Chassis	4 Chassis

In addition to fabrication, wiring, and inspection of chassis, five additional areas of work scheduled for the month of May were initiated. These were; 1) plan for main frame ground system, 2) power distribution and signal wiring of MAU, 3) fabrication and assembly of main power supply capacitor banks, 4) fabrication, assembly, and leveling of both core frame base sections, and 5) transfer of wired chassis from temporary frames to cast aluminum frames and wire wrapping connector pins. Initial stages of developing the D.C. power supply monitor hardware has also been started in the shops.

The main frame ground system was developed and the primary copper bus bars were installed with provision made for attaching the Malco wire wrap ground terminal strapping. These copper bus bars are placed such that they

serve for termination of all three vertical planes of ground strapping. Horizontal tie straps were inserted between each chassis frame and serve to both increase the area of the ground plane and to provide additional wire wrap grounding terminals. At present the first five bays of MAU's front, rear, and center walls have their ground strapping complete.

Power distribution cables supplying the D.C. voltages to the various chassis locations are fabricated and installed. Wire wrapping to frames is complete in bays 1 thru 6 front, rear, and center of MAU. All signal wires, both high-speed and remote indicator wires, are complete with the exception of the D^2 inputs. In flow-gating, both top and bottom row interconnecting wires between chassis are complete in rear bays 2 and 3 and front bays 1 through 6. Power cables are connected to the bottom 6 bays in front and to bays 2 and 3 in the rear.

Four power supply capacitor packages have been constructed with provision for accepting subassemblies of five capacitors each. A sufficient quantity of subassemblies are completed to fill these packages to filter the -50v, +25v, -5v and +6.8v supplies.

Both 1/2 core frame assembly bases have been constructed, leveled and positioned in the main computer room. The middle section members have been cut and milled and are in the process of being drilled and tapped.

Somewhat more time than anticipated was required in the chassis transfer operation, as preliminary reworking of the castings had to be accomplished prior to use on the main frame and on the chassis web. The castings were also number stamped for ease and accuracy in wire wrapping. A total of seventy-one chassis were transferred.

(C. E. Carter, H. E. Lopeman and Shop)

2. Testing of MAU Repetitive Chassis

As soon as sufficient aluminum chassis frames had become available, the repetitive chassis of the MAU (10 "QRM", 10 "A", and 9 "S" chassis) were subjected to a series of tests.

First, before any transistors were inserted, D.C. power was applied to each chassis. The voltages measured at each transistor socket pin and at various other points were compared with calculated values. This D.C. test discovered many faulty components, faulty or wrong connections, etc., without jeopardizing any transistors.

Secondly, transistors were inserted and each chassis was subjected to a dynamic test which exercised as many gates and selector paths as possible. This MAU test has been described in the March Progress Report. During this testing phase, intermittent behavior of components, faulty or missing solder connections, etc., were discovered.

Thirdly, the chassis were subjected to a "hammer" test which involved the tapping of solder points, terminals, components, etc., with a small mallet and rod made of insulating material. Faulty solder points, intermittently open diodes, etc., were found in this phase.

As a final test, each chassis was required to operate without error in one of the long Fibonacci cycles for at least one overnight run, at the end of which it had to pass a second hammer test.

Table 1 below presents the number of faults of various kinds, found and eliminated during these tests. The numbers are conservative, since the first set of chassis (QRM #2, A #1, S #1) had been checked out previously and since the recording of faults was occasionally overlooked in the heat of debugging.

Table I

Faults Found in 10 QRM, 10 A, and 9 S Chassis

Faulty or Non-Existent Solder Joints	79
Solder or Pieces of Wire Causing Shorts	3
Shorts Caused by Components Touching	8
Components Missing, Reversed, or Incorrectly Connected; Wires Incorrectly Connected	23
Broken Wire, Broken or Cracked Component	7
Faulty Indicator Bulbs	21

(Cont'd)

Table I (Cont'd)

Faulty Filter Capacitors	3
Open Resistors	25
Open or Intermittently Open Diodes	22
Shorted or Intermittently Shorted Diodes	2
Faulty Transistors	8

On the average, one chassis was checked out per day. Naturally, the speed with which faults were tracked down increased towards the end, not only because of the improvements in trouble shooting methods developed by the testers, but also because of the very evident improvements in chassis construction and wiring.

These tests, however, do not represent a complete check of the MAU chassis. The following signal and control paths were not involved in the dynamic test (although the gates had to be "off" to ensure proper operation):

Flow-gating to M register signal path and FgM,
R register to flow-gating signal path,
Carry generator to A adder selector path,
α* inhibit during carry assimilation.

Furthermore, the RvMgM and R·MgM gates were always used together.

(C. E. Carter, M. Melman, G. Metze, A. P. Stone)

3. Delayed (Arithmetic) Control (D.C.)

3.1 Layout of the Arithmetic (Delayed) Control

It may be recalled that during April a new layout of the Delayed Control was made; however, it was made using only estimates of the cable driving circuitry required. The cable driving circuitry was designed in May, permitting the final modification of the layout to conform to the actual circuitry to also begin. As quickly as possible after a section of the layout is finalized the block layouts for the several chassis involved will be made and sent to the shop for fabrication.

An investigation by Messrs. Lopeman and Krabbe revealed that many of the leads in the area of the EAU and end connections are in excess of 2 feet. As indicated in the April Progress Report this situation dictates the use of cables and the associated drivers.

A week was spent rearranging the layout in these areas to make room for the cable driving circuitry. As mentioned elsewhere, the shop is making the wiring layouts for the new cable driving circuits. As a result some minor changes in the EAU and end connection layout may be necessary, depending on the layout restrictions which the shop deems advisable. In addition some special circuit design is still necessary to avoid extra time delays and/or transistor expenditures.

Work is also in progress to complete the layout of the MAU center wall chassis. This involves the inclusion of the proper cable driving circuitry as well as added gate and selector drivers necessary to handle special control logic.

(S. P. Krabbe, H. E. Lopeman, J. O. Penhollow, and R. E. Swartwout)

3.2 Logical Diagrams for Delayed Control

Within the iterative portion of the MAU and the end connection area, both a schematic and a logical diagram have been made for each different chassis. It is felt, however, that within Delayed Control, chassis logical diagrams would be of little value; thus group logical diagrams and chassis schematics will be used throughout Delayed Control. There will be at least the following four types of group logical diagrams: sequencing control diagrams for each instruction group or subsequence; selector control logic; gate control logic; and status memory element control diagrams.

The design of the Delayed Control has progressed to the point where the drafting section can begin redrawing the logical diagrams for delayed control. It is desired that these diagrams will be sufficiently detailed to permit trouble-shooting and maintenance directly, without recourse to wiring diagrams. This objective cannot be attained unless precautions are taken to insure consistency and provision is made for addition of information not presently known.

The diagrams will contain the logic complete with cable drivers and level restoring circuitry, chassis and control area designations, pin and transistor numbers. To achieve these objectives, a set of drafting rules was established and published as File No. 374.

H. Aiso has made logical drawings of all the gate systems involved in delayed control. In keeping with the policy of debugging and maintaining the machine from logical drawings, these gate drawings contain chassis designations, pin and transistor numbers. All control areas which initiate a request for a particular gate are indicated as well as the control areas which receive the associated reply. The drawings include: the primary and secondary combining AND's, the reply NOT circuits, the $\overline{D}^2$ and D drivers for the register, and all the cable drivers required for communicating with these circuits.

(H. Aiso, J. O. Penhollow, R. E. Swartwout)

4. Cable Driving Circuitry

Investigation has shown that it is more economical to use a cable driving output from a restoring circuit than to use a separate cable driver circuit following the restoring logic. During May a set of 7 different collector output circuits was designed as well as the needed zener diode bleeders. The circuits are so designed that they can be added to any restoring circuit by attaching the Zener bleeder to either collector of the restoring circuit's switching amplifier (Dwg. No. C1117).

A file number and a basic circuit have been drawn up to describe the proposed new notation required to describe these cable driving outputs. The notation was chosen to satisfy two requirements. First, the symbol had to be compatible with the existing set of symbols. Secondly, the symbols had to be sufficiently definitive to enable the draftsmen, the shop and maintenance personnel to correctly identify the circuit or combination of circuits represented. This second point is essential if the policy of letting the draftsmen make the circuit schematic from the chassis block layouts is to be effective. A summary of the new symbols will be presented in the June report.

(H. Guckel, J. O. Penhollow, J. E. Robertson,
and R. E. Swartwout)

5. Core Memory

The model memory completed an error-free run of 308 hours, the longest single run to date. Several other runs were attempted, some of which were stopped by errors traced to bias current adjustment. Other runs were stopped by power supply failures.

All chassis construction for the final memory, except sense amplifiers ("SA" chassis), is complete and has been visually checked. Other items required to proceed with construction of the core memory are delayed by machine shop work.

(S. R. Ray)

6. Power Supplies

Five of the main power supplies (magnetic amplifier regulated) were received, four being "high" voltage (34v), one low (14v) voltage. The remaining two low voltage supplies are expected in the week of June 12. The installation of these supplies is awaiting installation of I-beams in the power supply room by the Physical Plant Division who, in turn, are delayed by delivery of the beams.

One of the power regulator modules (which will be located at the base of the computer) was received and tested to some extent. It was found to perform adequately, except that (1) the air flow path is more congested than was desired and (2) the -50v series regulator transistors are believed to be operating too near their reverse collector-emitter voltage rating. Both of these are simple to correct.

The control circuits for the D.C. voltages are being constructed.

(S. R. Ray)

Loads for testing the main supplies were designed and constructed.

(B. E. Briley)

7. Magnetic Drum Memory

Most of the control circuits appearing on the Magnetic Drum Memory block diagram have been reduced to detailed logic diagrams using the "slow" circuits. Some of the details are mentioned below. The bit timing portion of control including the delay lines and the associated circuits has not been completed.

A double rank sector counter composed of "slow" circuit F-elements was designed, built and tested. A problem was discovered in the operation of the F-elements; it is now being investigated by the "slow" circuits group.

An alarm circuit was developed. This circuit insures that the sector counter remains synchronized with the drum by requiring that (1) eight sector pulses occur every revolution of the drum, (2) the sector counter is in the 111 state each time the origin pulse occurs, and (3) an origin pulse occurs after every eighth sector pulse. Otherwise the alarm is energized.

A test circuit for simulating the sector and origin clock tracks was designed, built and tested. It produces eight (sector) pulses on one wire followed by one (origin) pulse on another wire, and then repeats. The circuit is driven by a square wave generator. It contains 33 N250 transistors.

(M. Falleni)

A small magnetic disc memory was received on loan from Vermont Research Corporation, Springfield, Vermont, the company which is currently building the two 1.8 million bit magnetic drums. The disc contains provisions for mounting heads in 13 different positions at radii from 3.091 to 4.531 inches, and track spacings from .025 to .040 in. It will be used for experiments on writing, reading, crosstalk, etc.

An experimental model of a one-bit section of the 4 x 8 head selection matrix was designed and wired, and is to be tested. This circuit includes the diodes and row and column select transistors associated with 32 heads, plus a write amplifier and some of the column drivers.

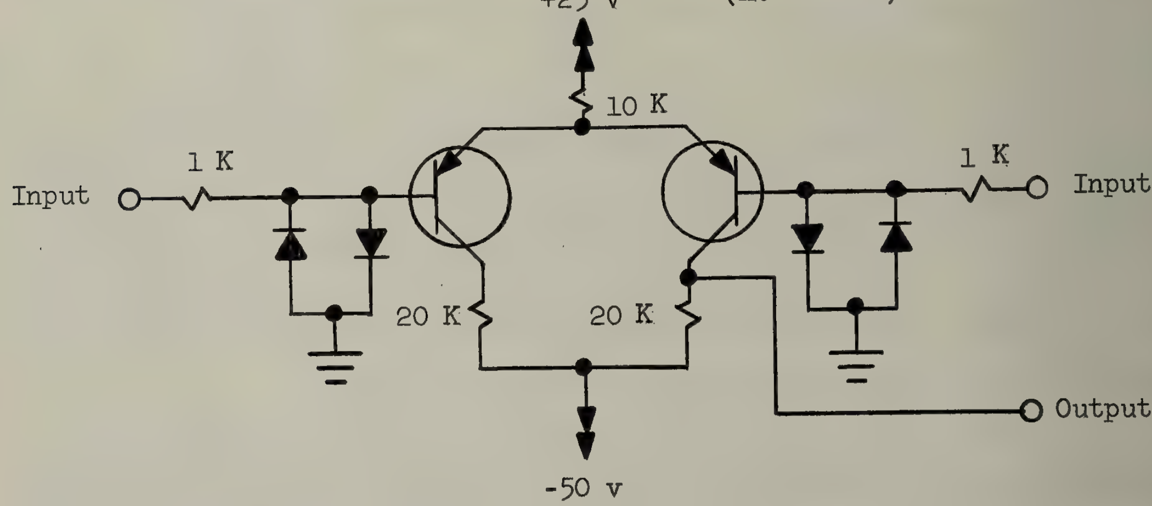
The "slow" circuits were used to synthesize a gated Eccles-Jordan circuit for use as a read register, i.e. the element which follows the read amplifier and threshold detectors. A circuit comprising a single gated Eccles-Jordan and a double gated Eccles-Jordan was developed to form a read register with error correction for the case in which the read pulse spreads (falsely) into the preceding bit position, but does not spread into the following bit position.

(P. V. S. Rao)

A direct-coupled read amplifier was designed, built and tested. The circuit consists of a difference amplifier and limiters as shown in Figure 1. The output voltage is proportional to the difference of the input voltages, thus cancelling common mode inputs such as the head selection signals. The voltage gain of this circuit is about 200.

Some problems were encountered in measuring the inductance and impedance of the 32 heads received from Vermont Research Corporation at frequencies in the 250 KC range. The best measurements so far have been made with a GF 916 AL RF Bridge.

(H. Yazaki)



Transistors: N250
Diodes: S577G

Figure 1
Direct Coupled Read Amplifier

8. Paper Tape Equipment

The logical design of the reader circuitry has been completed, and construction of the drive circuits started.

(C. S. Wallace and personnel of the Coordinated Science Laboratory)

9. Interplay Equipment

It has been decided that it is well worth while in terms of relaxing the otherwise extremely tight timing requirement on interplay to treat the drum on a special basis. The suggestion is to provide a separate transistor address counter for the drum, and to allow it and the rest of interplay to compete on equal terms for access to the main memories. This change allows one to guarantee that the drum need never wait more than 3 memory cycles to get access. It also allows a change in the interplay timing which ensures that memory time is never wasted by interplay's holding onto a memory without using it, and a simplification of the interplay channel controls which should more than make up for the cost of the drum's address counter. The capacity of the interplay system will now be:

a) Fast (Drum) Channel: one word every 5-6 μsec, depending on the core memory speed.

b) The total average word rate of all other devices must not exceed one word every 6 μsec, and no single device may have a word rate greater than one per 12 μsec.

The maximum possible word transfer rate is therefore a word every 3 μsec.

(C. S. Wallace)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

During the month of May, C. Afuso found a deficiency in the two-wire low-swing storage element and corrected this by developing a new gating circuit. R. Crow was able to design a diode steering counter using setting pulses of 5 mμs width. H. Guckel worked on tunnel diode theory, the check-out of the flow-gating chassis and the theory of cable drivers. All the major subjects are discussed below.

2. Cable Drivers

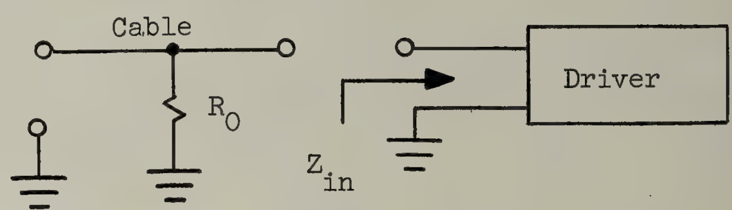


Figure 1

Cable Impedance Matching

In order to terminate the cable directly, it is necessary that in Figure 1

$$|Z_{in}| \gg |Z_0| = R_0 \ .$$

The magnitude of Z_{in} was studied by noting the occurrence of reflections as a function of the input rise-time for current controlled emitters. No difficulty seems to exist with rise-times of about 5 nanoseconds or more. This checks very well with the calculated data which predicts matching difficulties with rise-times of 2 nanoseconds or less if a GF45011 is used.

Some thought was given to the optimum use of the transistor as a driver. It must be realized that current levels of 40 to 60 ma have to be handled. This means that the selection of a suitable saturation margin becomes very important. In particular, the α degradation for the GF45011 becomes so bad that its practical usefulness in a driver is doubtful. However, the S-166 seems to have a reasonable saturation margin. Since, for a collector output, the matching network is only needed at the receiving end, the termination should occur entirely at one end only (see Figure 2).

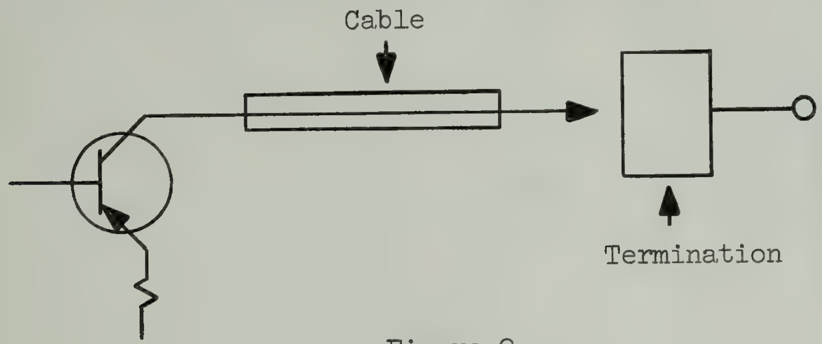


Figure 2
Collector Driver

A study of the termination itself shows that the switching impedance, if diodes are used for instance, should always equal the cable impedance. In other words, it is impossible to build a trick circuit obtained by assuming switching fast enough so that the cable does not react during the transition. As far as the transistor itself is concerned, the collector stage does not represent the best solution. The circuit in Figure 3 was studied:

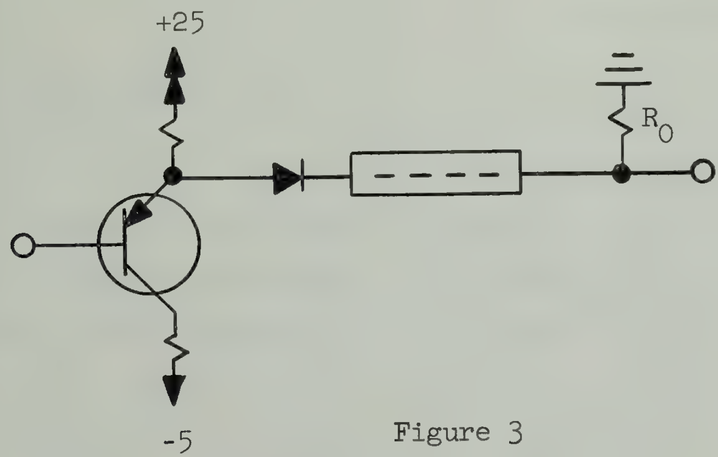


Figure 3
Emitter-Follower Driver

This circuit seems to be very fast. It does not rely on the constancy of α as much as a collector stage. The termination itself was studied more closely by considering the circuit in Figure 4.

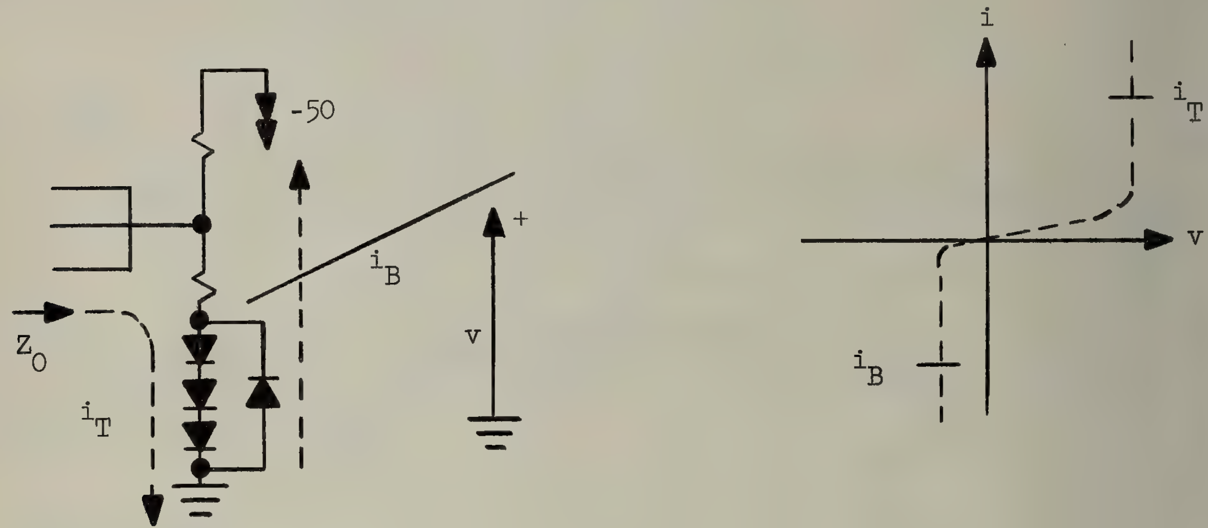


Figure 4
Cable Termination

Matching was accomplished in the i_T direction, whereas the i_B direction was not matched. The circuit did not offer many advantages. The matching in particular is difficult. Replacement of the diodes, which may be looked upon as a fast Zener, with a tunnel diode showed fine results but was rejected as impractical.

3. <u>Collector Steered Flipflop</u>

Figure 1 shows the conventional Zener coupled difference amplifier flipflop, with the addition of two triggering diodes. A positive triggering scheme is discussed since ideally the triggering sensitivity to a plus signal would be just the base emitter turn-off voltage, whereas to turn the OFF transistor on (with a negative pulse) the back bias on the ideal signal required would be the emitter base back bias plus the emitter base turn-on voltage.

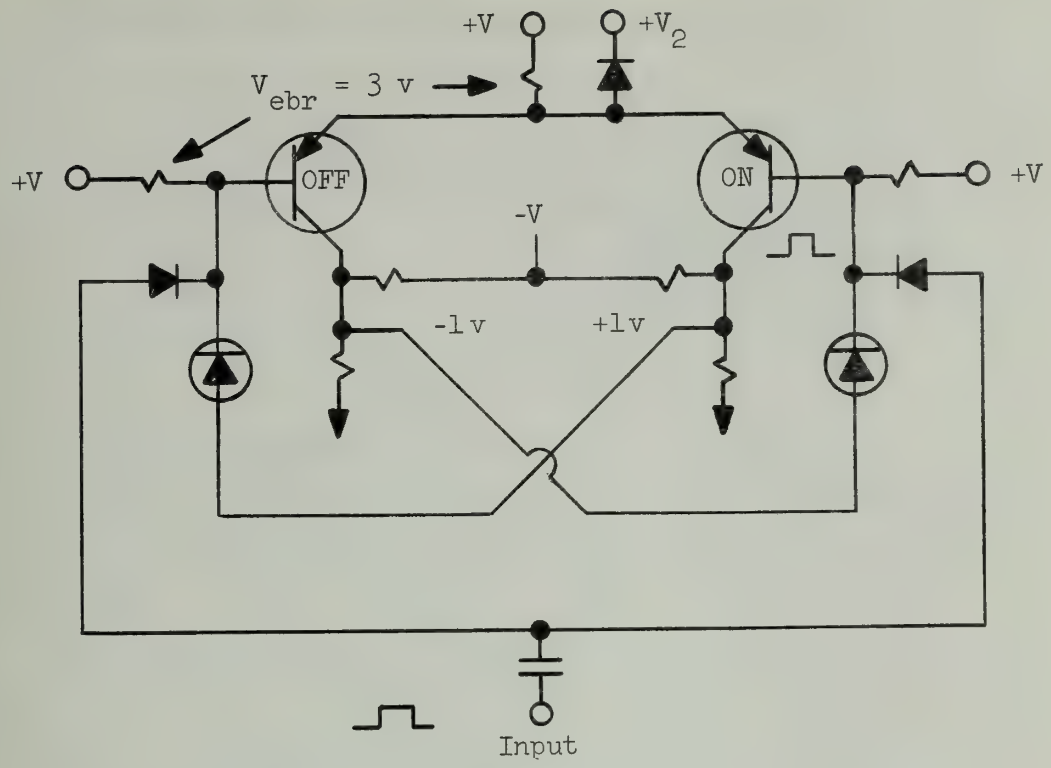


Figure 5

Steered Flipflop Collector

As usual, a positive pulse will appear at the point which is most negative: this is the base of the ON transistor. Ideally the steering is effective for a pulse amplitude equal to the peak-to-peak collector swing.

The emitter bump diode, D_3 is required since, if the emitter is allowed to move, the positive pulse at the base of the ON transistor will not turn the transistor off, since the emitter will follow the base.

Assuming that the emitter is held at a fixed voltage and that the ON transistor (T_2) is switched off momentarily so that its collector voltage goes negative by 2 v (ideally of course), it ensues that in order to insure a change of state, this swing must be greater than the emitter base back bias on T_1 (the switching loop gain must be greater than unity too). Typically, this back bias is 3 v and in the case illustrated, the collector swing is not sufficient. Hence the circuit will not switch. Evidently, in order to increase the switching sensitivity the emitter base back bias must be less than the collector swing.

A circuit with improved switching sensitivity is shown in Figure 6.

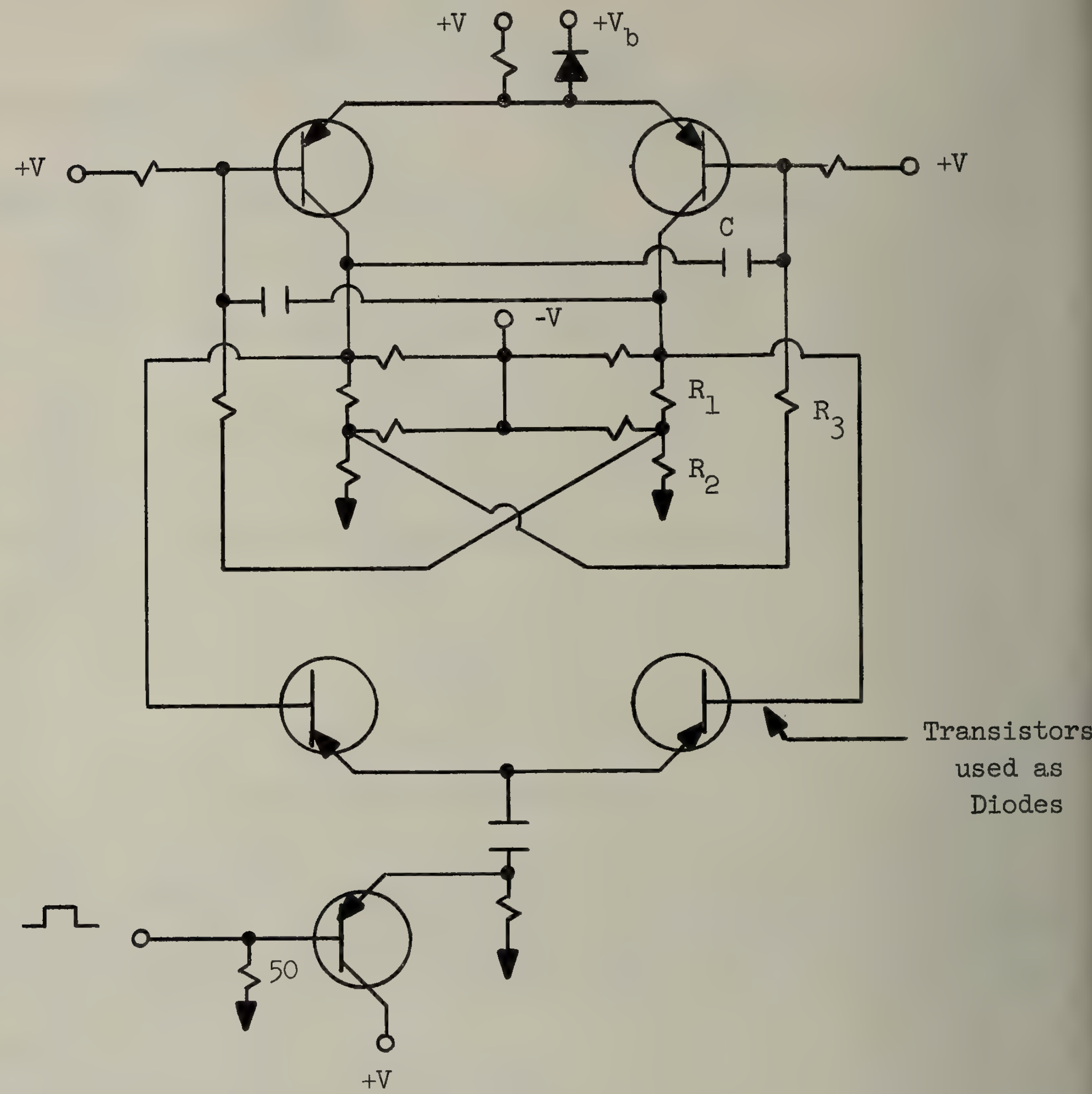


Figure 6

Improved Diode Steered Flipflop

The base swing is made less than the collector swing and only large enough to insure stability. The use of R_3 rather than a Zener as a divider increases the shunt impedance to the base triggering point.

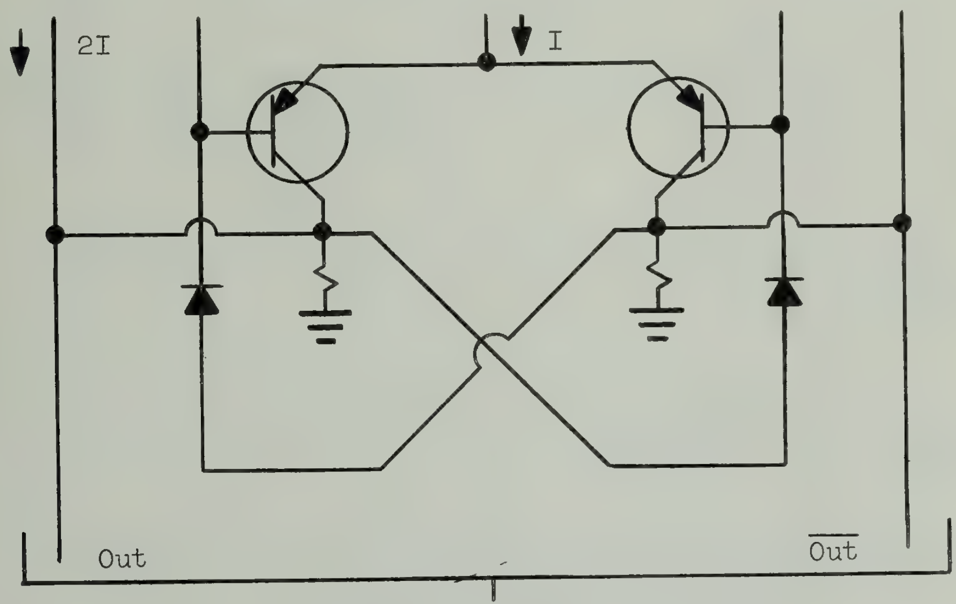
Once a divider topology is suggested, the question of optimizing the divider with respect to switching sensitivity, collector swing and repetition rate limitation due to coupling circuit time constant arises. Another speed limitation is the recovery time of the switching diodes.

A preliminary circuit, using $R_2 = 75\Omega$, $R_1 = 120\Omega$, $R_3 = 330\Omega$, $R_4 = 1.2$ K and C = 25 μμf has been tested for impulse response. These constants produce a base swing of ≈ 0.9 v, and a collector swing of ≈ 2.5 v. The circuit will trigger with a 5 mμsec, 2 v ideal pulse from the Lumatron pulse generator. For a 10 mμsec, 1.6 v input to the base of the driver, the rise times are on the order of 15 mμsec, including a turn-off delay of approximately 4 mμsec. The circuit has not been tested for repetition rate limitations.

4. Low Swing Shifting Register

An error was found in the shifting register which was designed several months ago. This happened because of a peculiar characteristic of the F-element.

As seen in Figure 7, the signal must be at least 2I in order for the flipflop to be set. Therefore after the flipflop is set in its new state, the output voltage becomes three times the normal voltage (because of 3I), i.e., while the gate is opened, the output is 3 v, v being the



Signal to the next stage

Figure 7
Currents in a Low Swing Flipflop

normal switching voltage. On the other hand, while the gate is closed, it becomes v. In the block diagram shown in Figure 8, for G = 1, (gate open), [S'] would be 3 v. In order to keep F' closed [$\bar{G}$] also must be 3 v. As long as F' is closed [S] must be v, and hence [G] must be v. Thus the different magnitudes of the gate input voltage must be used, depending on opening the gate or closing the gate.

This is the crucial defect in the shifting register.

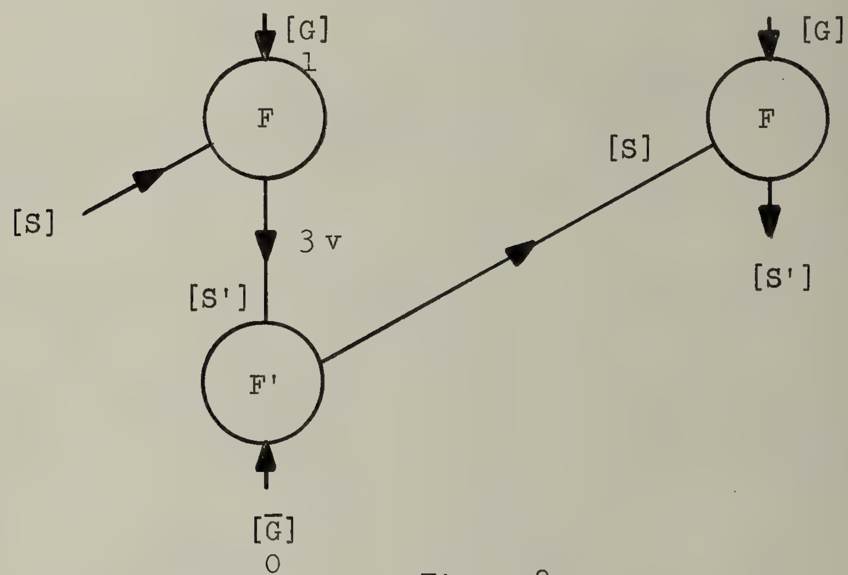


Figure 8
F-Element Chain

A new method of gating the flipflop was developed. The circuit is shown in Figure 9.

For a properly chosen low base voltage of T_g the current 2I of the driving difference amplifier goes through T_g so that the flipflop remains in its old state.

When a higher base voltage is applied to T_g, T_g is OFF and the flipflop is set to the new state dictated by [S].

Although the gate signal is not derived from a two wire system in one set of the circuits, the feature of the two-wire system would not be destroyed if the circuits are used in pairs in a shifting register.

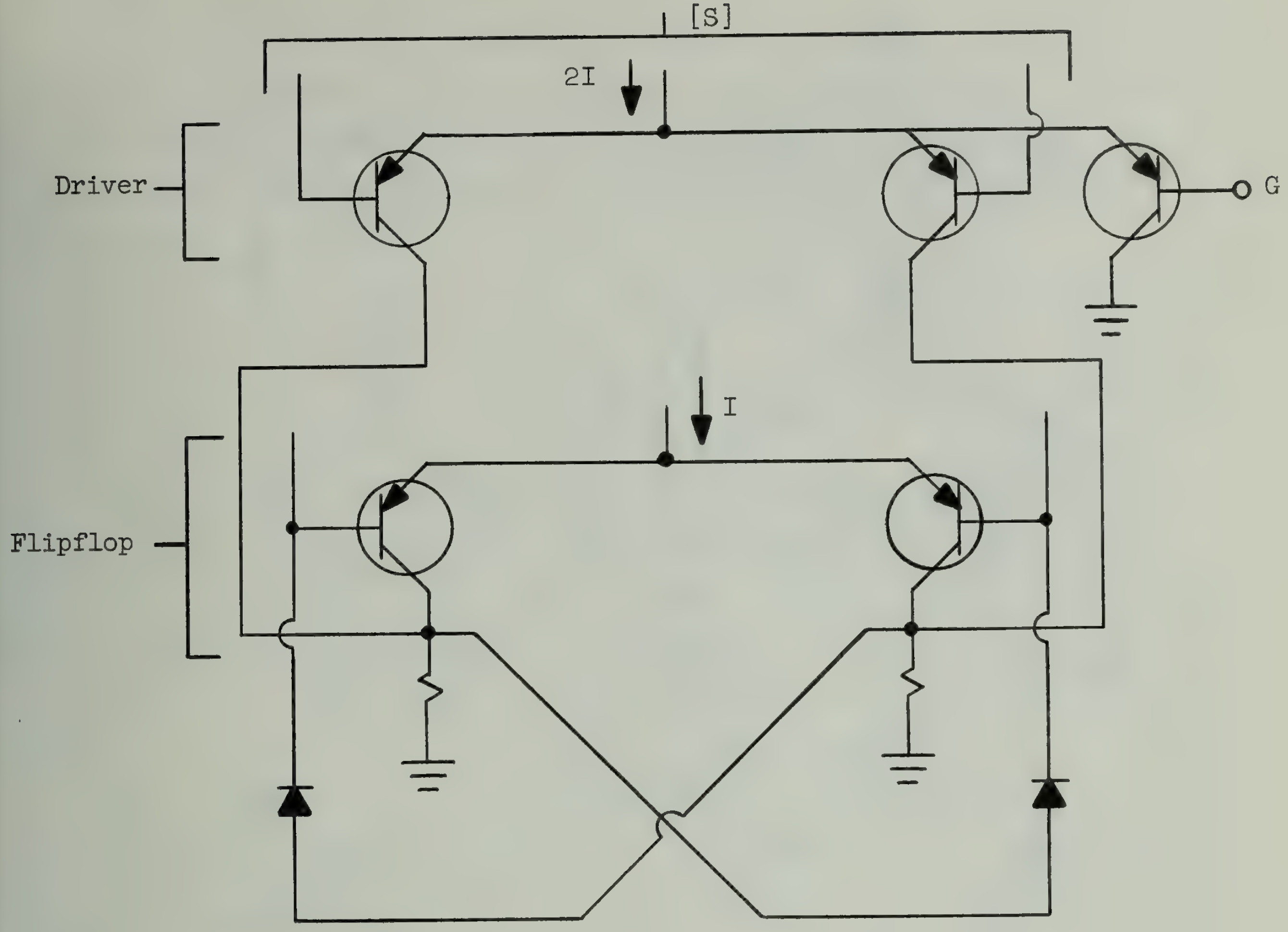
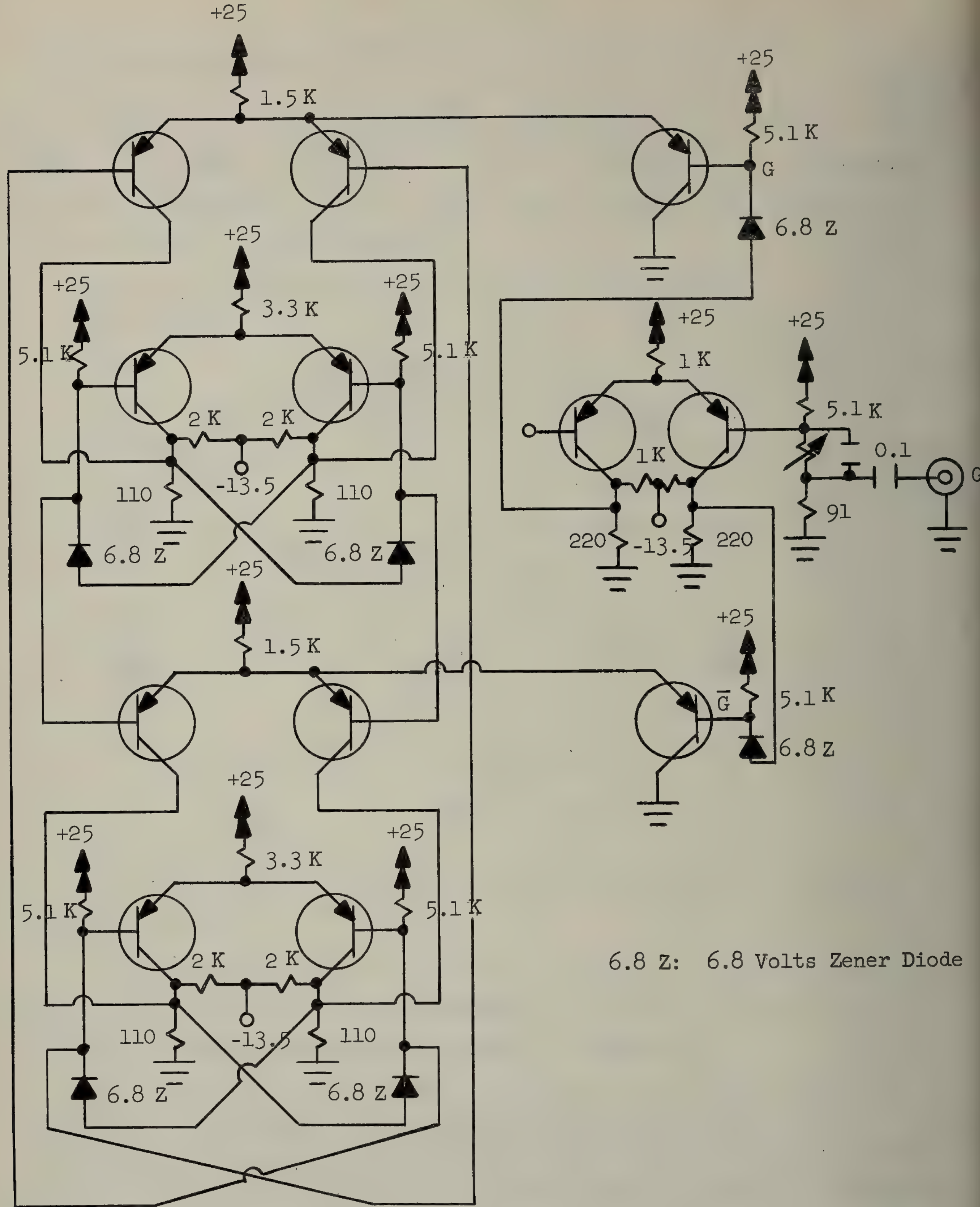


Figure 9

New Method of Gating Low Swing Flipflops

A test has been done for a one-bit shifting register. The test circuit is shown in Figure 10. Note that the test of a one-bit shifting register is possible because a NOT circuit is always included in a two-wire system circuit.

The circuit worked for a 40 mc gating input.



6.8 Z: 6.8 Volts Zener Diode

Figure 10

Test Circuit of One Bit Shifting Register

The free running frequency of the circuit without gating was observed to be around 40 mc. Since the frequency appearing in an F-element is one-half of the frequency of the gating input, shifting with a 80 mc gating signal seems to be possible. The typical wave forms are sketched in Figure 11.

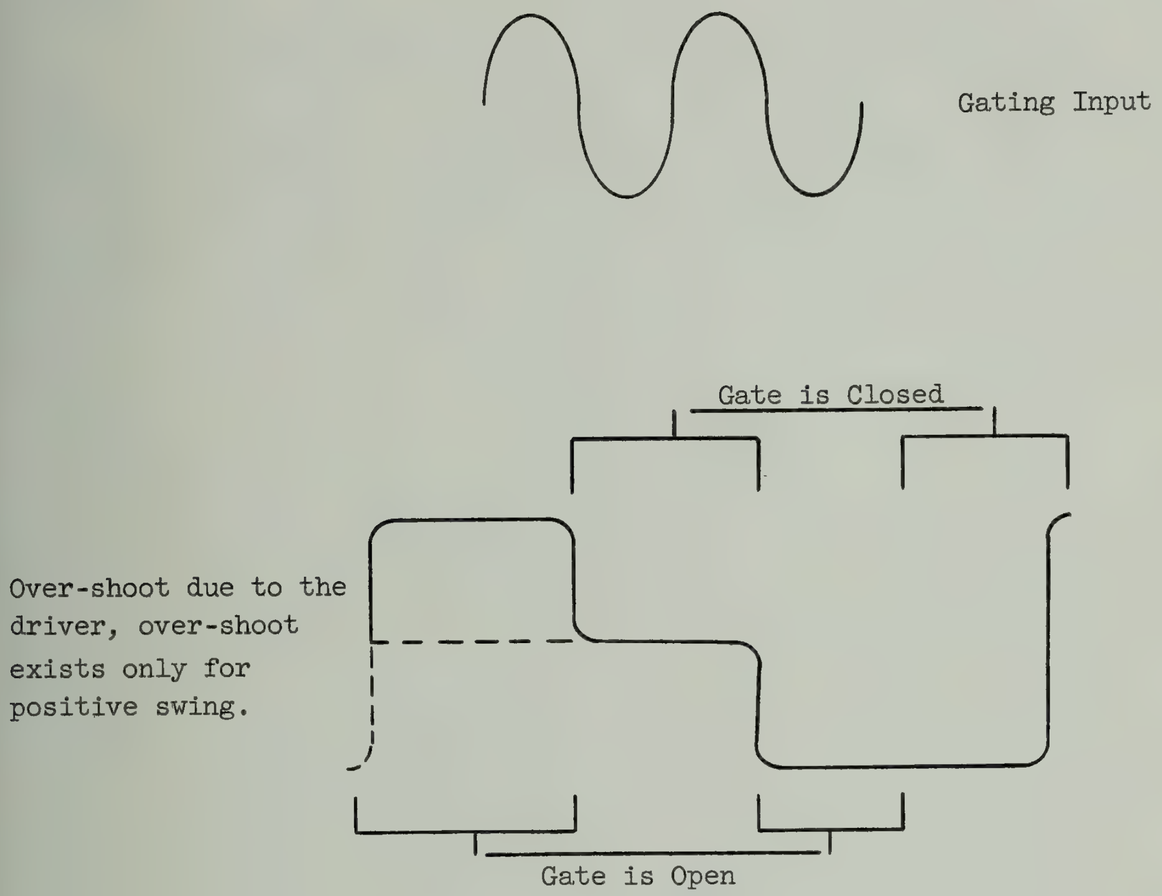


Figure 11

Waveforms in Figure 10

PART III

SWITCHING CIRCUIT THEORY

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Further modifications have been made in the procedure for analyzing asynchronous circuits first described in the progress report for June, 1960 and later revised and extended in DCL Report 104. One major change is the inclusion of a method of checking distributivity. The other changes are aimed at an increase in the efficiency of analysis of large circuits.

A "change path" is defined as a sequence of states of a circuit, formed by permitting just one node to change at each step in the sequence. The node undergoing the change is always taken as one which was not capable of changing in the previous state, i.e. a "newly-excited" node. The rules for combination and generation of change paths remain as described previously with the following exceptions:

A circuit can violate the distributive condition only at a point of interaction between two change paths. Accordingly, it is possible to verify whether or not a circuit is distributive at the same time one checks to see that a given interaction does not violate semi-modularity, if the latter procedure is modified in an appropriate fashion:

Whenever interaction of a given node of path A with some concurrently occurring change path B is detected, the terminal state of path A is retained and path B is retraced up to the point of interaction. The union of the two sets of excited nodes corresponding to these two cases is then formed. Next the union of the two sets of changes is formed, and the excited nodes for this case computed. Semi-modularity is then verified by checking these two sets of excited nodes against one another in the usual fashion--the first set must be a (possibly improper) subset of the second. Now, one can say that if the notation $\left\{E(X)\right\}$ denotes the set of nodes excited following the set of changes X, one can verify distributivity by verifying that

$$\left\{E(A)\right\} \cap \left\{E(A \cup B)\right\} \supseteq \left\{E(B)\right\} \quad \text{and} \quad \left\{E(B)\right\} \cap \left\{E(A \cup B)\right\} \supseteq \left\{E(A)\right\}.$$

Another addition made to the analysis procedure is that of establishing a means for determining when two change paths can be concurrent:

A table of precedence is created, on the basis of the transitive relation "is preceded by" ("is concurrent with" is not transitive.). A change path B is said to be concurrent with another change path A if B is not preceded by A. Thus at any point, one can determine which existing change paths can be concurrent with--and hence might interact with--a given change path A by consulting this table.

A final revision consists of the decision to alter the method of computing the effects of a given change. Whereas formerly the practice was to compute the values of all Boolean functions describing a circuit after each change, only those functions which are dependent upon the node allowed to change need be computed. In the revised procedure, this is what is done.

(W. D. Frazer)

PART IV

DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

AUTOMATIC REDUCTION OF DATA FROM BUBBLE CHAMBER PHOTOGRAPHS

1. Digital Tracking

A detailed analysis of 45 tracks that failed to track properly has disclosed that 75% of these could have been salvaged by an appropriate "gap" routine, i.e. a procedure for stepping across excessively gappy segments of track. On this basis a gap subroutine has been flow charted.

A highly schematic tracking routine using bang-bang digital control and the same extrapolation procedure as in the Illiac tracking routine has been written. This simplified tracking routine works on artifically generated tracks (with prescribed positional noise and gappiness), and will be used to analyze tracking stability conditions. Classical stochastic analysis (i.e. Wiener theory) allows only positional noise but does not admit gaps.

2. Factor Analysis of Pair Count Scores for Local Pattern Recognition

The first analysis of one plate (#4) scanned both by random selection and by prespecified human selection, and scored by the 16 pair counts (+ total point count) at two resolutions has been completed. The results at this stage are still fragmentary. However the essential results are as follows:

i) 4 principal factors are found, and correspond approximately to white-white, black-black, gradient counts independent of orientation, and finally a weak factor measuring excess of vertical over horizontal gradient count.

ii) pair count tests appear only weakly correlated with human specified taxonomy - i.e. beam track, electron spiral.

iii) factors appear invariant under change of scale (by factor of 2).

iv) factors appear approximately independent of whether domains were selected by random or by human.

v) for humanly selected domains, approximately 40% contain beam track (including confluence of 2 or more tracks), the remaining domains are electron spirals, globs, pseudo vertices, etc. This result emphasizes the difficulty of classifying local areas with purely a slit sampling system.

vi) the generic mean "grain" of this picture is a black cluster 4 cell divisions high, 1 1/2 cell divisions wide.

(K. Dickman, K. Hillstrom, M. Kuchnir, B. H. McCormick
F. Shimamoto, J. N. Snyder)

PART V

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of May, no new routines were added to the Illiac Library.

Illiac Usage

During the month of May, specifications were presented for 14 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 1944. Numbers followed by T are for theses.

1944 Digital Computer Laboratory. Partition Function of Two Interacting Particles. The quantum mechanical partition function for a system of two interacting particles in a box is computed. Boltzmann statistics are used, and a two-dimensional coordinate system is used. The interaction potential is a square well with a hard core.

The partition function is computed by the method of "path integrals", or, more precisely by the evaluation of certain conditional Wiener integrals. The "paths" are represented as Fourier series and a Monte Carlo sampling scheme is used to select coefficients in these series.

1945 College of Medicine. Analysis of Psychoanalytic Selection. Data was collected on applicants applying for training in a psychoanalytic training program. The data was collected over a three year period by group interviewers and individual interviewers. The data to be analyzed includes the scales on the interview schedule, along with other ratings such as those based on the applicant's credentials, the decision of the individual interviewer, the group interview team's decision, and the staff's final decision as to acceptability for training in the program.

Factor analysis of this data will reveal information on the extent to which such "factors" as perceptiveness, impulse control, etc., emerge and are stable over the three samples (years) of data; the extent to which these three groups of applicants differ on each of the variables; and possible differences

among the interviewers in the extent to which they perceive and weight the "factors" in the interview schedule and possible relations between the separate scale ratings and the factors and the decision criteria.

1946 Mechanical Engineering. Radiation Heat Transfer. This problem is an application of a general method for determining radiant heat transfer in enclosures. The specific problem is to determine the heat transferred by radiation between two long, gray, parallel, but non-concentric, cylinders. Each cylinder is maintained at a constant temperature.

An exact solution would involve the solution of three simultaneous integral equations.

The method used involves dividing the cylindrical areas into small enough areas so that the heat flux through each small area can be regarded as constant. The number of areas selected is 36. An energy balance is then written for each of these areas considering the net radiation leaving each area, due to radiation originating at one particular area. Because of symmetry only 20 such originating areas need be considered. This results in 20 sets of 36 simultaneous equations.

The coefficients in these equations are functions of the geometry and the surface emissivity of a given area. The coefficients have been calculated to seven places. If time permits, a finer subdivision will be considered, and compared.

In any case, the presence of an isothermal gas between the cylinders will be considered as a second step. This will add an additional equation.

1947 Physics. Zeeman Spectra in Neon. This program computes the Larde "g" factor by observing the frequency splitting $\Delta \nu$ in Zeeman splitting in a magnetic field H in Neon, where $g \approx \frac{\Delta \nu}{H}$.

Illiac is used to convert directly from traveling microscope measurements of spectral lines (n arbitrary lines), using orders of interference 5 - 10, (Fabrey Perot interferometer) to the values of $\Delta \nu$, then assumes value of g for one line, calculates H for all field possibilities on that line and uses these Hj's to calculate g on the other n - 1 lines.

1948 Physics. Fit to Breit-Wigner Lineshape. In experimental measurements of resonance absorption of nuclear radiation (Mössbauer Effect), it is necessary to determine several parameters of the transmitted spectrum. This spectrum has a lineshape which can be closely approximated by a Breit-Wigner function of the form

$$\text{Transmission} = D - \frac{B}{C+(X-A)^2} ,$$

where D and B relate to the strength of the absorption, C characterizes the width, and A is the shift in energy due to chemical binding, etc.

This routine will determine optimum values of A, B, C, and D by minimizing the sum of the residuals of a number of experimental values of X and T.

1949T Psychology. Moral Judgments and Neurosis. This thesis research is concerned with the relationship of moral judgments to psychoneurosis. On the basis of Freud's theory that neurotics have severe and rigid superegos, it is predicted that they will obtain higher scores than normal people on a "Moral Judgments Inventory" which has been constructed to indicate superego functioning. From Mowrer's theory which holds that neurotics have a weak and unassimilated superego, the opposite prediction is made. A third and integrating view is proposed which holds that some neurotics may have very weak superegos, while other neurotics may have very strong ones, and that the direction and intensity and consistency of this deviation will be related to certain neurotic syndromes and personality variables.

T-tests will be used to compare two male groups, that is, 100 neurotics and 175 normals (the latter being defined as men without a history of psychiatric or psychological treatment) with regard to Moral Judgments scores (total as well as part scores). The F-test is to be applied to see if neurotics and normals differ in their variability around their group, as well as around their individual average. Correlational methods are to be used to determine to what degree neuroticism in general, specific aspects of neuroticism, and other variables relate to moral judgments.

Since the various ways instinctual needs and demands of socialization are integrated in personality development is assumed to result in different personality types and superego functions, a factor analysis of persons is planned.

About 50 persons with scores on 51 items will be the basis for a cross-products matrix. A subject's score on each item will be multiplied by the corresponding score of another subject and an "average cross-products" score obtained by dividing by 51. Such cross-products (average) will be computed between all possible combinations of the 50 persons yielding a matrix of 50 by 50 persons. The factor analysis will be performed on this matrix to determine whether dimensions of persons can be ascertained and if so, what characteristics differentiate them.

Standard library routines are to be used in this factor analysis.

1950T Civil Engineering. Analysis of Variance for Completely Randomized Design. This problem is an engineering study of Humic-Gley soils in Illinois. These soils are regarded as trouble makers in highway engineering. One of the aims of this research is to determine the variability of the index properties of each soil type. The significant differences of index properties between soil types can be determined by analysis of variance. This program is made up to perform the calculations for the analysis of variance.

1951 Economics. Demand for Whiskey. The problem is to estimate parameters for a simple demand model. Estimates will be obtained by two stage least squares, reduced-form single equation, and limited-information single equation methods.

1952 Electrical Engineering. Diversity Correlation. Data — in sets of two numbers — will be received on paper tape. Each set of two numbers will represent a signal strength as recorded by two receivers. A third data set will be formed by taking the larger of the two numbers in each case. The drum will be used.

Three distribution curves for this third data set will be plotted by use of the dataplotter.

1953 Electrical Engineering. Autocorrelation and Spectrum Analysis. This problem is a study of the surface of the moon from reflected radio signals by the use of autocorrelation functions.

1954 Psychology. Item Analysis of the Industrial Analysis Tests. The Industrial Analysis Tests consist of a number of items which have been developed into experimental batteries for objective measurement of vocational motivation. Using standard library routines, the computer is to be used to ascertain the structure of vocational interest, and to determine which of the items best measure these dimensions.

A basic factor analysis will be used to determine the structure. The routines used in this factor analysis will be as follows: Centroid (KSL 1.21), Oblimax (KSL 1.90), and Rotoplot (KSL 1.96). Basic factor scores will be determined by means of routines for Matrix Inversion (KSL 5.11) and Matrix Multiplication (M-12).

The item data and factor scores will each be normalized, using routine KSL 5.60; and, finally, the normalized matrices will be multiplied to yield a rectangular matrix of correlations between the items and the criteria factors.

1955T Agricultural Economics. Optimum Fertilizer Plans. Linear programming methods will be used to develop optimum plans for fertilizer use. The sensitivity of such plans will be tested for changes in price and resources available.

1956 Bureau of Educational Research. Analysis of Counselor Ratings. Twenty-nine characteristics of camp counselors were rated by six groups of campers. It is desired to analyze the interrelationships of these variables by standard factor analytic procedures.

1957 Home Economics. Study of the Effect of Composition of White Sauce on the Viscosity. This is a study of the effect of percent of dried milk, percent of flour, and size of cooking batch on a measure of viscosity and other scores of white sauce.

Table I shows the distribution of Illiac machine time for the month of May.

TABLE I

	Hrs:Min	
Scheduled Maintenance	57:39	
Unscheduled Maintenance	5:25	
Drum Engineering	7:37	
Leapfrog	2:29	
Library Development	2:05	
Classes	34:21	
Instruction	:17	
Demonstrations	4:25	
Wasted	:11	
		114:29

Use by Departments

Agricultural Economics	19:09
Agricultural Ec. (Appraisal 47 15 05 334)	:09
Agricultural Engineering	:08
Agronomy(0015-15-306)	2:27
Agronomy(36-15-65-400-38)	:35
Agronomy	2:19
Animal Science	2:54
Astronomy	:55
Bur. of Community Planning (84 16 383)	3:13
Bureau of Educational Research	2:17
Chemistry (NSFG-7336)	2:56
Chemistry (NSFG-5907)	:19
Chemistry	60:57
Civil Engineering (AASHO ROAD TEST)	3:59
Civil Engineering (NSFG-6572)	10:16
Civil Engineering	48:41
College of Medicine (NIMH-USPH M-637)	:03
College of Medicine	1:40
Coordinated Science Lab. (DA-36-039-SC56695)	60:15
Digital Computer Laboratory (NSFG-9503)	13:47
Digital Computer Laboratory (Nonr-1834(27))	4:54
Digital Computer Laboratory (US TR AEC-1018)	12:48
Digital Computer Laboratory	1:34
Economics (NSFG-7056)	2:21
Economics	4:31
Education	:04
Electrical Engineering (Nonr 1834(22))	4:27
Electrical Engineering (AF 33(616)6079)	2:25
Electrical Engineering (NOBSR 64723)	2:39
Electrical Engineering (IOWA G-1955)	:27
Electrical Engineering (Nonr 1834(02))	:27
Electrical Engineering (AF-7043)	:14
Electrical Engineering (AF-4622-25-314)	:46

Electrical Engineering (SL 85173)	:34		
Electrical Engineering	27:47		
Institute of Communications Res.(44-28-20-378)	5:07		
Institute of Communications Res.(USPHM-3941)	4:16		
Institute of Communications Research	4:22		
Inst. of Labor and Indus. Rela. (00 6010 300)	1:50		
Institute of Labor and Industrial Relations	1:10		
Institute for Res. on Except. Ch.(HE W SAE 8204)	1:04		
Institute for Research on Exceptional Children	2:34		
Marketing	2:14		
Mathematics	11:47		
Mechanical Engineering (DA-11-022-ORD1980)	:05		
Mechanical Engineering	6:18		
Mining and Metallurgical Engineering (TRUS AF6770)	:51		
Mining and Metallurgical Engineering (CML 51F)	:23		
Mining and Metallurgical Engineering	1:29		
Music	4:17		
Natural History Survey	:04		
Petroleum Engineering	2:35		
Physical Education	:15		
Physics (Nonr 1834(05)A)	2:30		
Physics	26:36		
Psychology (1715)	3:58		
Psychology (MD 2060)	:41		
Psychology (M-1733)	:20		
Psychology	50:29		
Sociology	1:21		
State Water Survey (DA-36-039-SC75055)	7:42		
State Water Survey	5:59		
Theo. and Applied Mechanics (DA-11-070-508 ORD)	1:29		
Theoretical and Applied Mechanics	2:47		
Veterinary Physiology	:09		
Williams College	9:56		
		467:35	
			582:04

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind,

a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Memory		1
Reader		1
Punch		1
Drum		6
Unknown		3
	Total	12

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/1/61	20:30	:00	3:30	0		:00	:11	0
5/2/61	21:00	:15	2:45	1	(1) Unknown	:00	:14	0
5/3/61	20:53	1:37	1:30	3	(1)(2)(3) Drum Failure	:00	:13	0
5/4/61	19:33	1:40	2:47	2	(1)(2) Drum Failure	:00	:03	0
5/5/61	22:16	:00	1:44	0		:00	:00	0
5/8/61	21:18	:00	2:42	0		:00	:40	0
5/9/61	20:55	:00	3:05	0		:00	:00	0
5/10/61	21:05	:00	2:55	0		:00	:00	0
5/11/61	21:15	:00	2:45	0		:00	:00	0
5/12/61	21:47	:00	2:13	0		:00	:00	0
5/13/61	24:00	:00	:00	0		:00	:00	0
5/15/61	21:18	:00	2:42	0		:00	:02	0
5/16/61	21:35	:00	2:25	0		:00	:13	0
5/17/61	21:14	:00	2:46	0		:00	:00	0
5/18/61	20:53	:05	3:02	1	(1) Light on "Reader K" burned out	:00	:00	0
5/19/61	21:45	:40	1:35	1	(1) Memory pos. 15 failing	:00	:10	0
5/20/61	23:49	:00	:00	0		:11	:20	0
5/22/61	20:56	:11	2:53	1	(1) Unknown	:00	:00	0
5/23/61	22:00	:15	1:45	1	(1) Drum Failure	:00	:07	0
5/24/61	21:04	:00	2:56	0		:00	:06	0
5/25/61	20:00	:00	4:00	0		:00	:00	0
5/26/61	21:25	:05	2:30	2	(1) Punch "5" jammed. (2) Unknown	:00	:10	0
					(cont'd.)			

TABLE III (cont'd.)

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/29/61	21:30	:00	2:30	0		:00	:00	0
5/31/61	21:01	:00	2:59	0		:00	:00	0
TOTALS	513:02	4:48	57:59	12		:11	2:29	0

PART VI

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New 650 Codes

During the month of May, one new routine was added to the Digital Computer Laboratory 650 Library.

L1' - 72' A Floating Point Program for the Solution of Simultaneous Linear Equations with Sparse Matrices. In most engineering applications involving simultaneous equations, the coefficient matrices contain relatively few non-zero terms per equation. Standard routines for solving these equations require the storage of the entire coefficient matrix, including all zero elements, and thus put serious limitation on the size of matrix that can be handled in the fast memory of the computer.

The method described in this writeup eliminates the storage of all zero elements, thus increasing the effective storage capacity of the computer and enabling it to handle matrices of considerably larger size.

The Guass-Seidel iteration procedure is used and an automatic over-relaxation technique is incorporated to accelerate the convergence of the solution.

(A. A. Elassal and
S. J. Fenves)

International Business Machines 650 Usage

During the month of May, specifications were presented for 17 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 247'T. Numbers followed by T are for theses.

247'T Theoretical and Applied Mechanics. Peak Amplitudes in Multi-Degree-of-Freedom Systems Having Damping and Applied Harmonic Forces. The research problem is concerned with multi-degree-of-freedom systems having viscous damping and applied harmonic forces at different points in the system. The amplitude of each mass in the system will be determined and compared to those occurring at the resonant frequency.

The solution of this problem involves solving sets of simultaneous equations.

248' Agronomy. Soil Test Evaluation. A variation of fifty determinations from the same soil test sample will be compared for pH, phosporus, and potassium.

249' Petroleum Engineering. Evaluation of Porosity and Fluid Saturation from Well-logs. Mathematically, the program involves selecting certain portions of data from a larger set of data, i.e. a "sorting routine".

250' Psychology. Test Score Stability. This problem represents part of a continuing project concerned with test score stability. The Airman Classification Battery AC-2A was administered to students at the Aviation High School, New York, in 1959 and in 1960. The AC-2A contains eight individual aptitude tests and four aggregate indices. The product moment correlation between the 1959 and 1960 test scores will use data from the 812 students who took the test both years. Correlations between identical tests and means and standard deviations of each individual test and index are required.

251'T Veterinary Physiology and Pharmacology. Estrogen and d.l. Methionine on Blood Coagulation. The effect of estrogen and d.l. methionine on blood coagulation and hemorrages in rats fed a vitamin K deficient diet is to be studied by the method of least squares.

252' Physics. Fitting of Scattering Cross Sections by Legendre Polynomials. The routine K7'-68' (Library) is used to analyze some experimental scattering data for $\pi^- - p$ at energies 770 mev, 640 mev, and 440 mev. These data are read from published papers (Walker, et. al.). The aim is to compare the scattering at these energies with the data and results at higher energies and to try to establish a phenomenological description of the back-scattering.

253'T Mechanical Engineering. Orthogonal Cutting Formulae. It is desired to evaluate 27 simple expressions depending on 7 parameters. Normally a minimum of 30 minutes is required to evaluate one set of parameters by hand. In a parameter study of this nature, the running time required should be little more than that for printing the answers on the 407.

254'T Psychology. Dimensions of Preference. Using a program "Paired Comparisons from Balanced Incomplete Blocks" input data from a questionnaire involving 31 objects, arranged in 31 blocks of 6 objects each, will be analyzed to give the paired comparisons matrix and scale values from this matrix.

The least squares solution for scale values is used. Scale values are computed, using the normal deviate, the arc sine, and the logarithmic transform.

An auxiliary data checking program will also be used to insure that the input cards are in proper form.

255' Finance. Traffic Impact Study. The research problem is an attempt to describe the influence of traffic conditions upon land values in Champaign-Urbana. Approximately 26 variables are used to explain value differences. Multiple regressions (prepared via Illiac) indicate a need to study interdependence between explanatory variables.

The K-7' library routine will compute X^{L}_{s} for selected frequency distribution of the variables studied. Additional frequency tables will be prepared with the K-3' routine, if these tables and X^{L}_{s} are needed.

256' Statistical Service Unit. Electronic Scheduling Research. Data necessary for research on Electronic Scheduling will be converted from cards to magnetic tape. These tapes will be used in the analysis and program development of the Electronic Scheduling system for the University.

Logic sections of the final program will be tested with 650 pilot programs using the above data.

257' Physics. Reactor Burnup Studies. The problem to be studied is one of reactivity as a function of the burnup. The reactivity can be calcu-

lated when the concentrations of the various isotopes and fission products are known. The burnup or concentrations in a two region reactor can be found by solving a system of approximately 20 first order ordinary differential equations.

258' Physics. Electric Field Gradients in Crystal Lattices. The electric field gradients in point-ion and uniform-background lattices are to be computed. This problem is similar to one previously done except that more general equations are to be used which are valid for any angle between crystal axes.

259'T Chemistry. Steric Requirements for Neighboring Group Participation in Some Cyclic Sulfides. The solvolysis reactions of a number of cyclic chlorosulfides proceeding through intermediate bicyclic sulfonium ions and following first-order kinetics have been studied to determine the effect of structure on reactivity. One case studied was the 3-chlorothictan solvolysis. This has given evidence for a novel bicyclic sulfonium intermediate. It is desired to express the uncertainties in rate constant in terms of standard deviations. Sixty-eight tests were made with approximately 10 pairs of observations, rate and time, taken on each. The IBM 650 will be used to calculate the means, standard deviations, and regression coefficients for four curves:

$$t = x$$
$$t = \log (a_1 - x)$$
$$t = \log (a_2 - x)$$
$$t = \log (a_3 - x) \quad .$$

260' Physics. Two Group Criticality Study. The neutron flux in a simple reactor core can be described by means of the solutions of certain characteristic equations (eigenvalue problems). The relevant differential equations have discontinuous coefficients taking in account the different composition of core and reflector respectively.

The solution of the eigenvalue problem is obtained by solving the characteristic determinant, which involves the various parameters in transcendental form.

In this problem a parameter study will be made, varying core and reflector size against fuel concentration in the core under the condition of criticality of the system, which means that the above mentioned parameters together with all other parameters being held constant have to satisfy the characteristic determinant.

261'T Civil Engineering. Behavior of Pile Group Under Lateral Load. In this experimental set-up, bending moment is to be measured along the pile length with the help of foil strain gages. By twice differentiating and twice integrating the bending moment and other diagrams numerically, soil reaction and deflection diagrams will be obtained.

262' Natural History Survey. Fish of Champaign County. Five drainage systems in Champaign County were examined to determine which species of fish were present and which habitat characteristics were present. The IBM 650 will be used to compute means, standard deviations, regression coefficients, etc. in order to determine the significance of geographic habitat on the abundance of some fifteen selected species of fish.

263'T Agricultural Economics. Land Values in Relation to Regional Development. The average values being obtained from these computations (price per acre, acres per sale, assessments per acre, etc.) will be used for describing the effects of regional developments on land values. The original data include all bona-fide farm land sales in Illinois for the years 1953-57. These average values will therefore be used in various statistical analyses (such as a regression analysis) to test hypotheses concerned with land values and regional development.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of May.

TABLE I'

		Hrs:Min	
Scheduled Engineering		14:39	
Unscheduled Engineering		16:33	
Tape Testing		5:34	
Library Development - DCL		19:20	
Classes		45:05	
CE 391	15:53		
Math 295	29:12		
Demonstration		:09	
Wasted		3:49	
			105:09

Use by Departments

Agricultural Economics		16:01
Agronomy		6:53
Animal Science		4:21
Astronomy		2:23
Chemistry		14:37
Civil Engineering		23:11
Digital Computer Laboratory		:24
Electrical Engineering		:13
Graduate College		8:18
Mechanical Engineering		6:10
Mining and Metallurgical Engineering		9:40
Physics		12:26
Psychology		4:36
Small Homes Council		1:12
Sociology		4:06
State Water Survey		6:38
Statistical Service Unit		121:00
Admissions and Records	3:08	
Agricultural Economics	3:38	
Agricultural Extension	:42	
Bureau of Educational Research	2:35	
Bureau of Institutional Research	2:27	
Bursar's Office	6:46	
Business Office	18:16	
Chemistry	1:49	

(cont'd.)

Civil Engineering	:35			
DHIA	32:52			
Economics	:06			
Education	19:36			
Finance	:43			
Forestry	:02			
Horticulture	:31			
Marketing	3:53			
Navy Pier	13:11			
Psychology	:11			
Statistical Service Unit	2:10			
Student Counseling Service	7:49			
Theoretical and Applied Mechanics		4:07		
			246:16	
				351:25

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 11:30p.m. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for May.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPE OF FAILURE CAUSING STOP
5/1/61	11:39	3:51	:15	:02	2		(1) 533 read continued to cycle. Start switch replaced. (2) 533 did not completely punch out card. Loose screw found.
5/2/61	14:57		:22	:23	1		(1) Tape unit didn't load properly.
5/3/61	15:53			:07	2		(1) Multiple bits in pos.8 of accumulator. (2) Multiple bits in pos.8 of distributor.
5/4/61	15:47			:09	1		(1) Col 30 didn't read from card.
5/5/61	14:52			:46	0		
5/8/61	12:10	3:38		:00	0		
5/9/61	19:55		2:20	:05	3		(1) 407 cycling when shouldn't. Relay 31-2 burnt. (2) Pos. 5 of dist. gets multi bits when soaping. (3) 407 spacing improperly. Adjustment in carriage and proper tension necessary.
5/10/61	15:09			:21	0		
5/11/61	13:29		2:11	:14	1		(1) Tape unit 1 reading incorrectly. Bad tube found in unit.
5/12/61	15:43			:18	1		(1) 407 continued to cycle when forms ran out. Burnt relay points found.
5/15/61	12:37	3:08		:00	1		(1) Multiple bits in positions 1 and 4 of program register.
5/16/61	14:41		:51	:09	3		(1) Tries to write on tape 8011 when program calls for 8010. Bad tube found in unit 1. (2) Could not read from tape unit 3. IBM tests ran OK. (3) Read errors from tape from different tapes and units.
5/17/61	13:00		3:05	:05	2		(1) Soap routine looped. Reason unknown. (2) Col 40 of card not read by 533.

(cont'd.)

TABLE II' (cont'd.)

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPE OF FAILURE CAUSING STOP
5/18/61	14:22		1:01	:13	2		(1) Special characters in cal 60 not reading correctly. Bad tube found in 655. (2) Power kept cutting off in 533. Found the felt padding had been moved.
5/19/61	12:20		1:50	:10	1		(1) Pick up both binary lights in pos. 8 of upper accumulator. Bad tube found.
5/22/61	11:26		4:17	:10	2		(1) 407 would not read alpha input correctly. Found broken circuit breaker. (2) 407 carriage would not restore. Found dirty contact.
5/23/61	15:33			:04	2		(1) Tape reading errors on units 1 and 2. (2) 407 stopped cycling. Later started OK.
5/24/61	15:06		:21	:16	3		(1) Card jam in 533 punch. (2) Read difficulty with soaping on unit 2. (3) Card jam in 533 read.
5/25/61	15:16			:07	0		
5/26/61	15:42			:04	0		
5/29/61	11:11	4:02		:00	0		
5/31/61	15:36			:06	1		(1) Read errors on units 1 and 3 when set on 8012.
TOTALS	316:34	14:39	16:33	3:49	28		

TABLE III'

533 card read punch		8
Read side continues to cycle	1	
Punch not completely punching	1	
Read error	3	
Power break	1	
Card jam	2	
407 accounting machine		6
Continues to cycle	2	
Spaces improperly	1	
Alpha not reading correctly	1	
Carriage not restoring	1	
Refuses to cycle	1	
727 and 652 tape units and tape control		8
Unit not loading properly	1	
Unit reads incorrectly	5	
Wrong unit selected through control	1	
Cannot read from unit	1	
650 console and magnetic drum unit		5
Multiple bits	5	
Unknown		1
Program looped	1	
	Total	28

PART VII

GENERAL LABORATORY INFORMATION

Seminars

"Basis for a Mathematical Theory of Computation", by Professor John McCarthy, Massachusetts Institute of Technology, Cambridge, Massachusetts, May 1, 1961.

"Round-off Error in Matrix Computations", by Dr. J. H. Wilkinson, Mathematics Division, National Physical Laboratory, England, May 2, 1961.

"Magnetic Thin Film Memories", by Mr. Jack I. Raffel, Lincoln Laboratory, Lexington, Massachusetts, May 8, 1961.

"A Simulation Study of a Polymorphic Computer", by Professor Norman R. Scott, University of Michigan, Ann Arbor, Michigan, May 15, 1961.

"Perceptron Neurodynamics", by Dr. Frank Rosenblatt, Cornell University, Ithaca, New York, May 22, 1961.

Reports

Report No. 109, "Variation with Size of Characteristics of Electric Circuit Components Having Gain," by John L. Muerle, May 19, 1961.

Personnel

The number of perople associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	10	1	10.75
Visiting Faculty	0	0	-
Research Associate	3	0	3.00
Graduate Research Assistants	9	25	22.75
Graduate Teaching Assistants	0	5	2.00
Administrative and Clerical	7	1	7.33
Other Nonacademic Personnel	40	15	45.33
Total	69	47	91.16

The Laboratory Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbaum, J. E. Robertson and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - CIRCUIT RESEARCH PROGRAM

PART III - DATA REDUCTION METHODS

PART IV - ILLIAC USE AND OPERATION

PART V - IBM 650 USE AND OPERATION

PART VI - GENERAL LABORATORY INFORMATION

June, 1961

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PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Physical Aspects of Machine Construction

1.1 Chassis Frames

Because of difficulties in the manufacture of the terminal boards the chassis frame orders mentioned last month were delayed. Out of 100 pairs of chassis frames only 7 pairs were delivered in June.

(C. E. Carter, T. E. Kerkering)

1.2 Air Conditioning

The input and output air ducts for the air conditioning are complete except for insulation and wrapping.

The air handling units are in place, are connected, and are ready for operation. The compressor and heat exchanger on the roof have been checked.

(Lee Whyte and Physical Plant)

1.3 Flow-Gating

It was decided to put all of flow-gating into the machine for the first phase of operation rather than just the bottom row. Because of this all 24 outer wall chassis of flow-gating were checked. The checks covered the flow-gating words but not the selectors in the top chassis of flow-gating.

(H. Guckel)

1.4 MAU Tests

D.C. testing on the QRM, A and S repetitive chassis was completed, and testing was started on certain of the smaller MAU chassis (i.e., C-976, Driver-Driver A_{3C} and A_{5C}; C-977, Driver-Driver QRM_{3C}).

(A. P. Stone)

1.5 Shop Progress

	MAU	Flow-Gating	1/2 Core
Complete	41	24	45
Lack Male Frames	6	6	3
Lack Diodes and Inspection	1	1	
In Wiring Stage		6	
Parts Shortage	1	2	4

In addition to the regular wiring load the shop has played a major role in the following:

Positioning of main power supply units and preparation of power supply room.

Fabrication and installation of power supply output capacitor banks.

Preparation of Rowan relays for mounting in power supply room.

Construction, wiring and installation of the main frame monitor unit.

Inspection and modification of eleven (11) regulator modules.

Fabrication and wiring of monitor indicator control panel on the computer main frame.

Installation of the 1/2 core memory frame in position in the computer room.

(T. E. Kerkering, F. P. Serio and Shop)

2. Drawings and Layout

2.1 Revised Drawings

After a review of end connections it was possible to being the following drawings up to date.

1020 - Q6F	1008 - Q7F	1022 - Q5R
1002 - A6F	1000 - A7F	1024 - A5R
1006 - S6F	1004 - S7F	1026 - S5R
1028 - Q6R	1050 - Q7R	968 - Q4C
1016 - A6R	1048 - A7R	969 - S4C
1018 - S6R	1046 - S7R	

Basic circuits brought up to date are

B1107, B1108, B1110
C949
B963
B947

3. Layout of the Delayed Control

During the month, the block layouts of 15 chassis containing either MAU end connections or EAU have been released to the shop. As far as the stem of the "T" is concerned, the only outside wall areas not laid out are bays 8F and 8R. These areas contain the last of the EAU and end connections and some portions of Delayed Control. These layouts have been held until the design of an Eccles-Jordan memory element with cable driven outputs is completed. As soon as this design is complete, the layouts of these two bays will be given high priority.

In addition to the aforementioned work which is closely associated with Delayed Control, one entire centerwall bay of Delayed Control has been laid out. This is bay 16CR which contains the sE, sEA and sD selector controls. In addition to the block layouts, the final logical diagrams for these selector

controls were prepared. These diagrams give the complete picture of the selector operation from control area to request area to control logic to the selector gate drivers to the reply system as described in the May report.

(H. Aiso, S. P. Krabbe, H. E. Lopeman
J. O. Penhollow, R. E. Swartwout)

4. Design of Advanced Control, Phase Zero

During June, a flow chart and the corresponding logic diagrams for AC_0, the phase zero advanced control, have been prepared. The logic diagrams are complete except for cable drivers and associated terminations.

Since AC_0 is intended to be a temporary, unsophisticated version of the final Advanced Control, care was taken to minimize the extent of the changes necessary when AC_0 is ultimately replaced, but to nevertheless use the memory, control counter, etc., in a fashion similar to their ultimate use. The ultimate use has not yet been defined in some cases.

The equipment to be used in phase zero consists of the arithmetic unit, flow-gating memory, delayed (arithmetic) control, one core memory, a paper tape reader, a paper tape punch, and AC_0. AC_0, including the control counter, will be located in the Interplay area on top of Core I. Although all of the flow-gating memory chassis will be used since the flow-gating selector is required, only the IN and OUT registers will be used by AC_0.

The following special characteristics of AC_0 are worth noting:

> Parallelism in operation is restricted to fetching of the next order word from memory by AC_0 while arithmetic control operates on the previous operand.
>
> At most one operand memory access is allowed per instruction. Information is transferred to IN, or from OUT. Thus, DC instructions Add and Store Clear, Subtract and Store Clear, Store with Exponent Equal, cannot be performed. Furthermore, DC instructions which store information in modifier registers will have their effect reduced, since AC_0 stores from OUT only.

An order word consists of one address and one instruction.

Each instruction consists of 15 bits, 9 bits for AC_0 and 6 bits for DC.

(AC_0 does not decode the DC part; any information needed by AC_0 must be provided redundantly in the AC_0 part of the instruction. The DC part will not differ from the ultimate DC instruction except that certain bits may be complemented to simplify the wiring of the bootstrap into the core stack.)

In addition to furnishing Delayed Control with the appropriate instruction, AC_0 can execute the following instructions:

1) Read operand from memory and send it to the IN register.
2) Store operand from the OUT register to memory.
3) Read one character from the Tape Reader and send it to the IN register.
4) Send one character from the OUT register to the Tape Punch and punch.
5) Jump
    a) unconditionally
    b) conditionally on accumulator positive
    c) conditionally on accumulator negative
    d) conditionally on overflow
    e) conditionally on zero
    f) conditionally on GREEN SWITCH center
6) Stop

Furthermore, any instruction can be modified to cause AC_0 to stop, after fetching the instruction, when the BLACK SWITCH is in the center position. (This makes it possible to alter the action of a program e.g. by setting the GREEN SWITCH at this point.)

Of course, instructions can be executed one by one by users of the WHITE SWITCH, and any instruction can be executed repeatedly by means of the ORANGE SWITCH.

Facilities are also provided to clear the memory by accessing the memory in successive locations. (It will be merely necessary to hold the CLEAR MEMORY switch up for more than about 8 milliseconds in order to clear all 4096 words.)

(G. Metze, R. E. Swartwout)

5. Advanced Control

Advanced Control can be considered to consist of one central control called Sequential Advanced Control (SAC), and several much smaller autonomous controls, namely ACR/DCR Control which reads the next order from flow-gating into the ACR order register, and, if appropriate, copies it into DCR for later execution by Delayed Control; Control Counter Control (CCC) which is reponsible for refilling the flow-gating order buffer registers F8 and F9, when required; Out-Write Control (OWC) which stores Delayed Control results either to the flow-gating memory or to a core memory; Store Control (SCO) which completes certain fetches from core memory to the flow-gating memory.

A number of very important simplifications in the behavior of this complex of equipment have been made. The action of CCC is now to copy the contents of an even numbered core location into buffer F8, and the next consecutive core location into F9, after the current contents of F8 and F9 have been used. This considerably simplifies the status memory elements previously required to define the contents and availability of F8 and F9, and allows the core memory C1 to be connected directly to F9 and C2 to F8. Also much of the elaborate equipment previously required for prefetching order words has been eliminated and the control counter has been reduced to a 12-bit single rank register which counts by using the AAU registers and adder.

The operation of OWC has been simplified, particularly as it appears to SAC. Previously, as soon as the OUT register (F0) had been loaded by Delayed Control, OWC began competing for BS (the output bus to the flow-gating memory) and also, for core memory write operations, the memory it required. The first consequence of this was that the output to flow-gating always had

to be interlocked to allow for a potential competition between OWC and either SAC or ACR/DCR Control. Secondly the interlock equipment became extremely complex, because the use of core memory was intimately tied up with the use of flow-gating. In particular, the interlocks had to prevent the possibility of one control getting BS while the other got the memory, which could cause a hang-up if each control required both. The simplification adopted has the property that only one of ACR/DCR Control, SAC, CCC or OWC ever wants to use BS or a core memory at any one time. In effect OWC is called into play only when either

(a) a second DC store order is encountered by SAC so OWC must complete its operation before accepting an instruction for the next operation,

(b) SAC encounters an order referring to the memory register (core or flow-gating) which is the destination register for OWC.

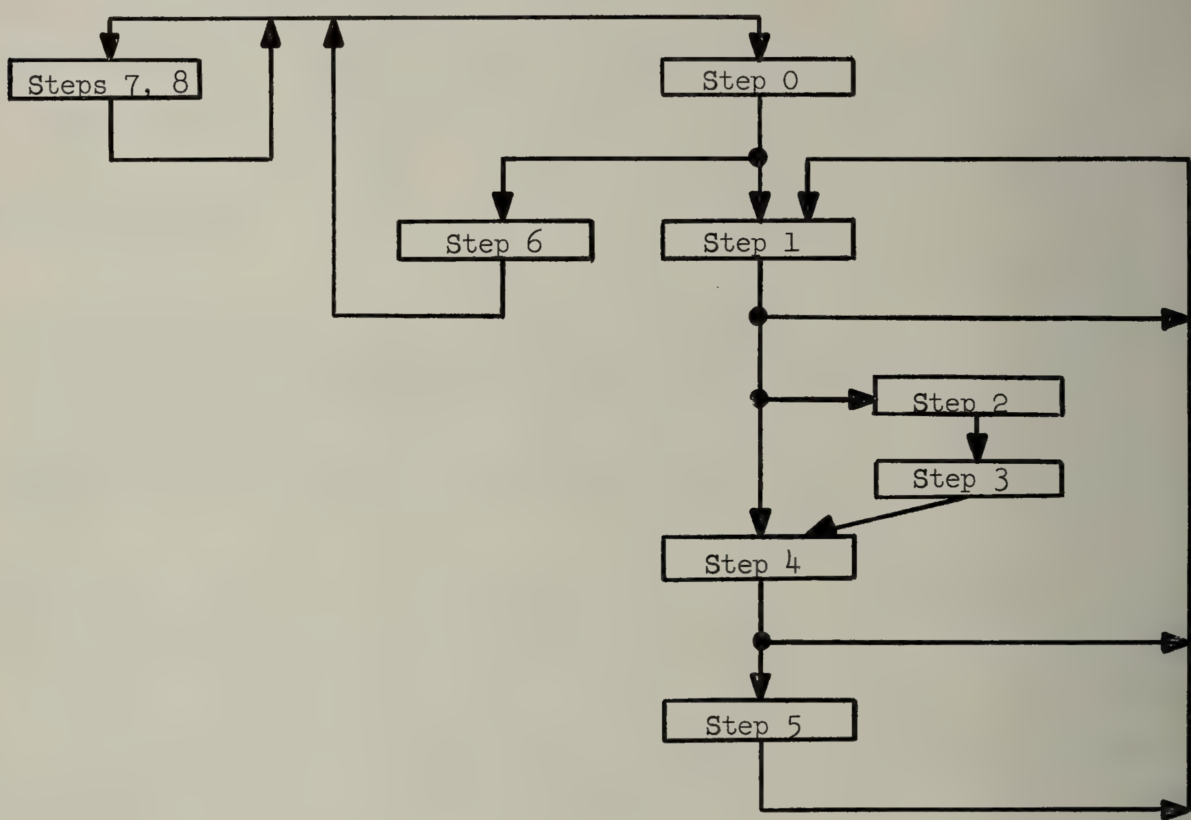
Earlier plans called for 2 store controls, one for each core memory, and required that every core memory fetch be initiated by SAC or CCC and completed by the appropriate store control - that is, the store control would compete with SAC, OWC and the other store control for sFG, and would copy the word or 1/4 word into its destination in flow-gating, and declare the register full. Theoretically, 3 flow-gating destination registers had to be locked-out and checked by each SAC order. Now only one store control is required, and its function is to complete the transfer of a core memory operand into the IN register. All other fetches are performed sequentially by SAC or in a parallel manner by CCC. This change slightly slows the orders Load Fast Register, Load Modifier and Load BO, in those cases in which the quantity loaded is not used by the instruction immediately following. The lock-out equipment is considerably simplified, since SAC now needs to check that one register is not referred to by OWC.

(D. B. Gillies, R. Shively, C. Wallace)

Sequential Advanced Control

The controls SAC and ACR/DCR Control are closely interrelated and have operations conditional on the Advanced Control order decoder. They may

usefully be drawn on one flow chart with the following structure



Most steps consist of a null step followed by a normal control step. Steps 0 and 6 comprise ACR/DCR Control and 1-5, 7 and 8 comprise SAC. Address construction or quarter word arithmetic are performed in 1, 2, 3 and reference to memory and the loading of auxiliary controls are performed in 4. Step 5 is used for completing memory transfers and adding 1 to the contents of an index register. Note that the next step 0 can be done in parallel with the execution of the current order. Steps 7, 8 may precede step 0 if interrupt is required.

Within this framework, a preliminary set of control sequences applicable to nearly all instructions have been prepared. These must be extended, checked and combined in preparation for the assignment of function digits to the order code. These control sequences were prepared by R. Shively.

During the month several alternative ways of prefetching order words were explored by C. Wallace and R. Shively. These were discarded in favor of the simplification to CCC described earlier.

6. Core Memory

6.1 Testing

Operation of the model memory was discontinued this month in order to mount the air blower in the final memory cabinet.

(S. R. Ray)

6.2 Noise Pick-up

An investigation was made to determine the core-plane wiring scheme which is optimum with respect to noise pick-up. It was found that a scheme which minimizes the distance between outgoing and return paths is best; it was also found that effectively twisting the wires by alternating end-connections with each traverse has a negligible effect.

(B. E. Briley)

7. Core Memory Block Checker

For purposes of communication with drum, paper tape, magnetic tape equipment and the like, the Core Memory is divided into 32 blocks of 256 words each. Access to any block is controlled by the state of a "Block Busy" flipflop, which is set if the block is being used by one of the devices mentioned above. These flipflops may be set by program, but may be cleared only by TIR. Any address sent to Core Memory must be checked first of all to see whether or not it lies in a busied block. This is done by the Block Checker, which decodes the 5 most significant address bits emerging from sCA. Provision is also made for setting or clearing any Block Busy flipflop. The polarity of a signal at the output of the Block Checker determines whether or not the

address is to be allowed. The entire unit, consisting of a decoder, the Block Busy flipflops and their associated gates, and a comparison network, contains some 560 transistors and should take about 80 ns to operate.

(M. Faiman)

8. Power Supply

Two 14 v magnetic amplifier power supplies were received which completes the order for all main magamp. supplies (7 total).

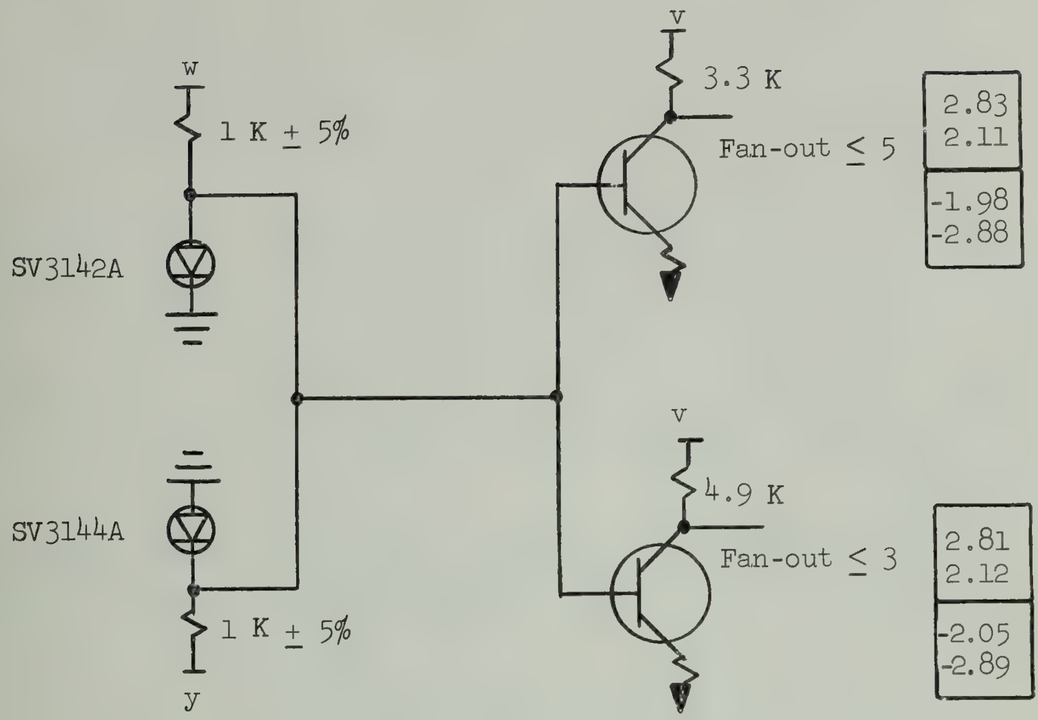
The 12 regulator modules have also been received which completes the order.

Wiring of the DC monitor circuits to the main frame was completed.

(S. R. Ray)

9. Altered Bump Voltage Levels for Fast Circuits

The bases of emitter-follower outputs from the standard fast restoring circuits are bumped positively to +X3 and negatively to -X5 to give output voltage bands of approximately $\pm$ (2.5 to 3.3) volts. For the Block Checker (and indeed for any highly repetitive logic) this entails a large number of bumps to be applied to nonrestoring logic. It has been common practice to alter the stabistor series resistor in bump circuits to change the resulting bump voltage, and an attempt was therefore made, with the help of SIR KITTSOLVER 2000, to alter the restoring circuit bumps in the Block Checker so as to be able to eliminate some 64 bumps. This was successful, and the NOT circuit that is proposed for use therein has the following type of output:



	Bump Currents (ma)	
	Max.	Min.
Positive	3.20	0.85
Negative	5.05	1.42

(M. Faiman)

10. Slow Circuits

10.1 Circuit Design

During the last few days of May and the first few days of June it was found that slow circuits would not perform the task as outlined.

The slow circuits are being redesigned in an effort to make them as insensitive as possible to slow rise and fall times. It is felt that it is possible to design a set of circuits which can handle infinitely slow rise and fall times. It is realized that this set cannot correctly generate all possible Boolean functions, but the attempt is being made to correctly generate all functions normally associated with circuit topologies encountered in this laboratory.

The transistor has been changed to a slower type device in order to get the higher emitter-base reverse voltage necessary for the design of these circuits.

The nominal voltage of the zener diode and of the bump supply have been changed to allow circuits with special switching thresholds to be driven from the standard emitter-follower.

It is realized that the new set of slow circuits will be slower than the old set, and an attempt will be made to regain some of the speed by increasing the supplied over-currents to the driven device.

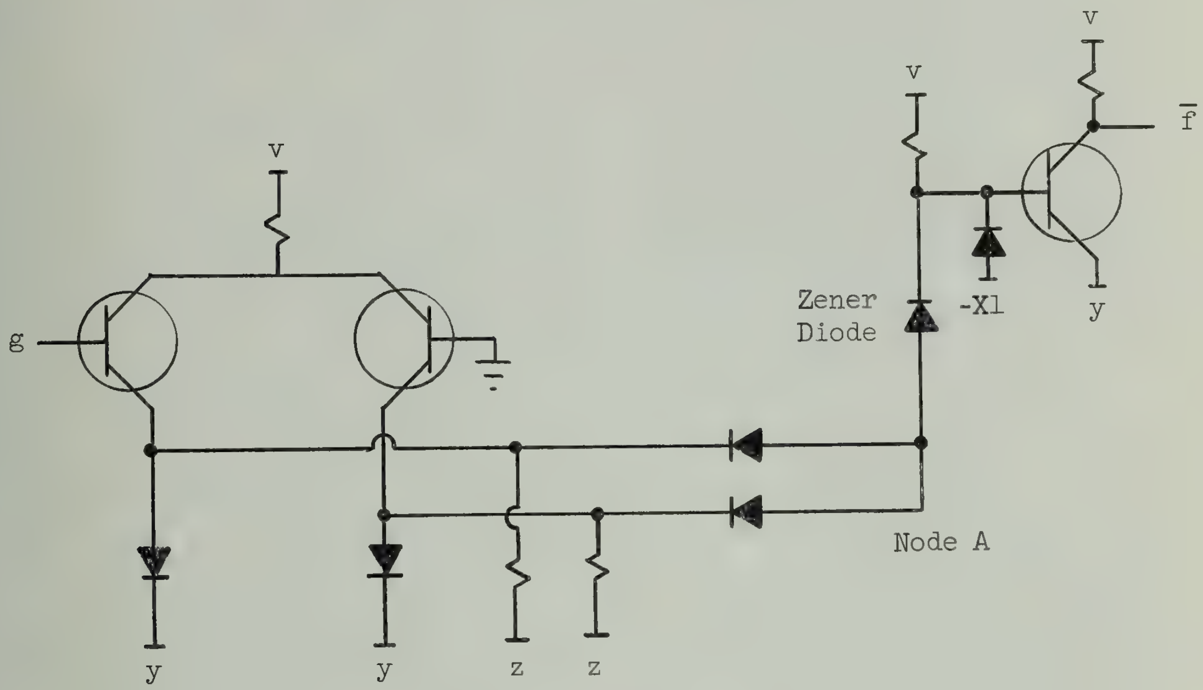
(M. D. Freedman, L. J. Peek, Jr.)

10.2 Slow Circuit Logic

The design of the 13-bit, double-rank Control Counter was completed and laid out for assembly on two 12 x 18 chassis. The design experience gained with this device was written up and embodied in a fuller account of the logical properties of the slow circuits - File No. 369, May 15, 1961.

Later experimental evidence disclosed that F-type (i.e. latch, or integral-gate) elements would not operate reliably because, during transition of the gate signal (g), there was a time when equal collector currents from the switching amplifier would drive node A sufficiently positive to lift the

output off the negative bump and into the "1" region. The effect of this was that the F-element lost its information as the gate turned off, if it had been set to "1" while the gate was on.



It was therefore necessary for these circuits to be redesigned (Section 10.1). In logical terms, the conclusions of File No. 369 are still valid - as far as they go. But the added provision, in the revised circuitry, for a restoring element of the (AND-OR) AND-type, with optional inversion between the AND and the OR, makes the system more powerful. In addition, the voltage levels at input and output are such that there are virtually no unusual precautions (File No. 369, Appendix II, 1:3 and 2:2) to be taken when communicating with standard fast circuits. Revised drawings are in the course of preparation.

As a result of the decision that Advanced Control organize order-fetches in pairs, the number of stages in the Control Counter has been reduced to 12 and a revised layout is currently being undertaken.

(M. Faiman)

11. <u>Magnetic Drum Memory</u>

Some experiments with the magnetic disc were performed during the month. It was found that a write current of 90 to 100 ma produced optimal read voltages over recording densities from 37 to 375 bits per inch (NRZ). Output voltage was found to be 100 mc peak-to-peak at 37 bpi, but dropped down to less than 40 mv peak-to-peak at 375 bpi.

(C. N. Liu)

The 4 x 8 head selection matrix and write amplifier which was built last month has been operated with the magnetic disc. A mean read signal of about 40 mv, peak-to-peak, full winding, was obtained at 280 bits/in. NRZ for write currents of 80 ma. The read signal amplitude at maximum packing density was nearly independent of the write current rise time up to about 0.6 μsec.

Transistor types 2N671, 2N600 and 2N397 were tested in the row and column select circuits. The 2N397 was found most suitable, because of speed, behavior under saturation, etc. The selection transients last less than 2 μsec for read currents of around 20 ma. The effective current through the head during switching (algebraic sum of currents in the two windings) is almost negligible, so that it probably will not be necessary to confine the selection process to the gaps between sectors. Transistor types 2N834 (Motorola) and X397 (Texas Instruments experimental) were tested in the write amplifier. The X397 was found more suitable.

The Read Register described in last months report has been built and is being tested using a clock track on the disc.

(P. V. S. Rao)

Some experiments were performed on a new read amplifier circuit to investigate the noise problem and the stability. It was found that the amplifier could recover from the overload caused by a simulated write voltage and return to its normal small signal gain in about 5 μsec.

Measurements of the inductance and impedance in the frequency range between 100 kc and 1 mc were made with the 6 heads received with the magnetic disc from Vermont Research Corporation.

(H. Yazaki)

The requirements of the magnetic drum memory bit timing circuits were investigated further, and the bit timing logic was partly designed. An experimental delay line circuit was built and tested. More work is needed to determine (1) the delay needed between the write and read strobes and (9) the delay which may be required by the single track error correction scheme.

(M. Falleni)

12. <u>Paper Tape Equipment and Interplay</u>

The 1000 cps paper tape reader has been run under conditions where it must stop from full speed on reading a character. Its performance has been quite satisfactory, the stopping distance being about 1/20th inch. Higher voltage transistors are being acquired to improve this performance, although it is already workable.

The two BRPE 110 cps punches have arrived. Work on the circuits for the core buffer registers for interplay has begun, and the early results are that the core setting and sensing speeds will be adequate.

(C. S. Wallace)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

What is possibly a break through in fast tunnel diode circuits was made by H. Guckel who investigated the design of a multi-phase transfer system in which each stage is self-clocked. Since no external pumps are necessary these circuits have been called "auto-pump circuits". The idea is to use the incoming signal for two purposes: to switch a tunnel diode and to produce in a short-circuited coaxial line an (inverted) reflected signal. The latter, after some delay, brings the tunnel diode back to its initial state.

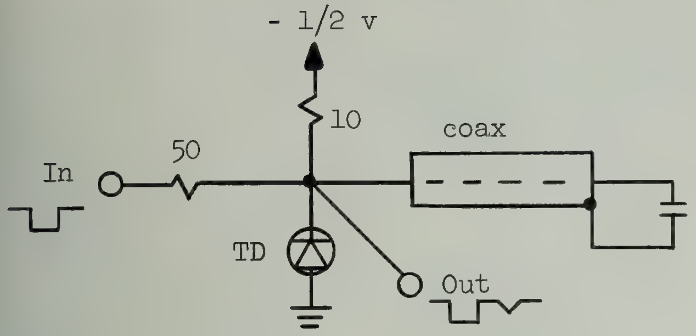
A program was initiated to study the behavior of equivalent transistor circuits at both high and low frequency. In particular it is hoped to gain some insight into the behavior of r_b and r_b' as saturation is approached. (H. Guckel and S. Ribeiro)

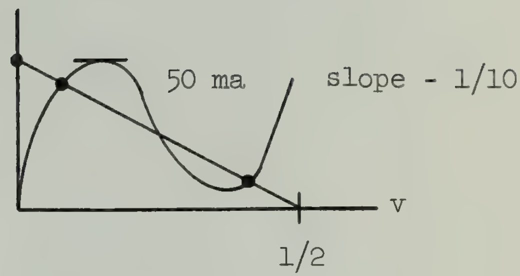
A counter using the low-swing circuits and probably capable of accepting 80 mc signals was designed by C. Afuso. Preliminary tests were promising.

R. Crow wrote a final report on his findings about counters using diode steering.

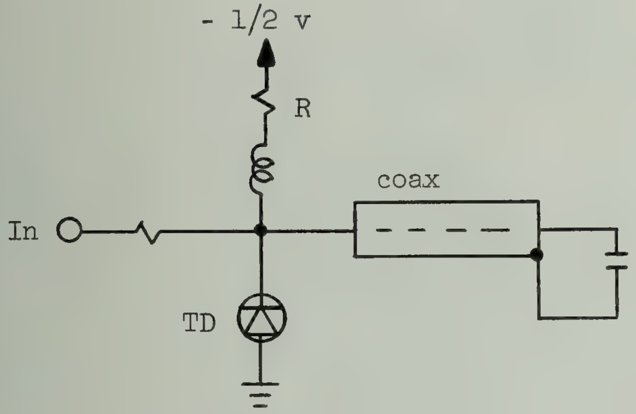
2. Tunnel Diode Circuits

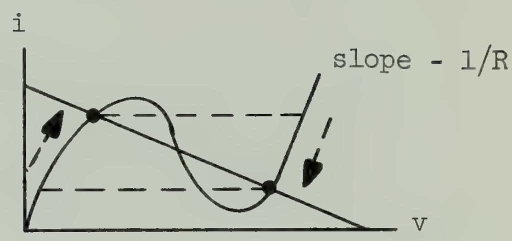
Experiments with RCA - pill box package diodes were performed on the circuits shown in Figure 1.





a) Amplifier and Slicer





b) Flipflop

Figure 1

Autopump Circuits

Time measurements are not yet accurate enough to be quoted: due to stray capacitance effects they differ by too large a margin. In order to eliminate this, an oversize board was designed and is currently being manufactured by the Electrical Engineering Department. This will be used to study the AND circuit of Figure 2.

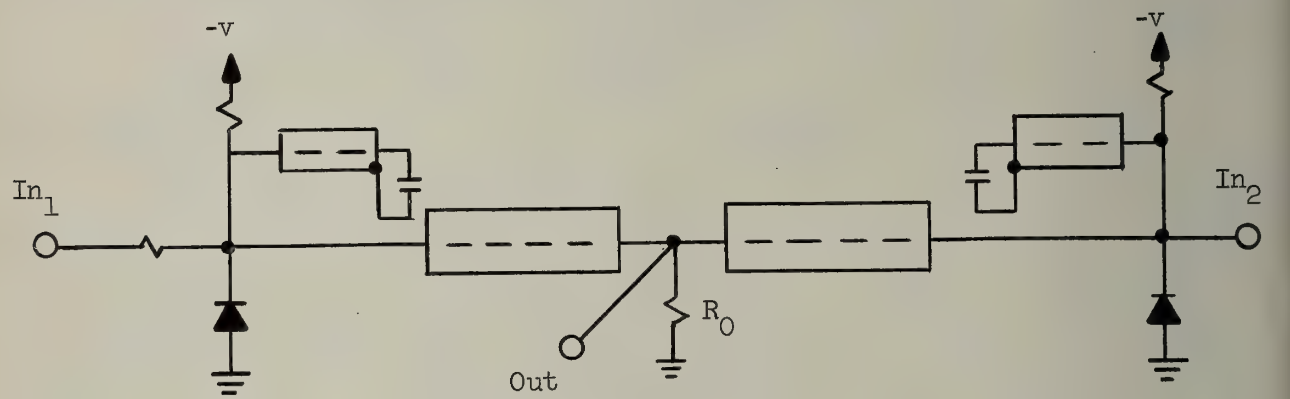


Figure 2
Autopump AND Circuit

The principle of these circuits is explained in the summary: the shorted coaxial line switches the tunnel diode back to its initial state after the signal has been amplified. The AND circuit is based on the idea that a suitable resistor R_0 can be found such that the output lines of the two amplifiers are approximately terminated and no reflection occurs. When both signals arrive at R_0 simultaneously, an analog addition furnishes an output signal above a certain level: this level is chosen just above the critical switching for the next amplifier stage.

These circuits have operated on pulses which were less than 1 mμs long, the rise and fall times being in the submillimicrosecond region.

3. Transistor Measurements

A jig according to Figure 3 was built to hold the 2N250, for which the geometry is known.

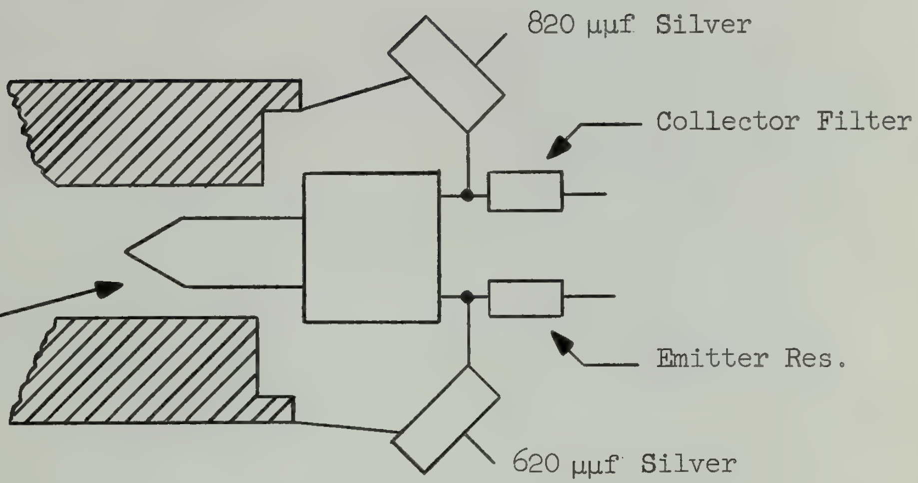
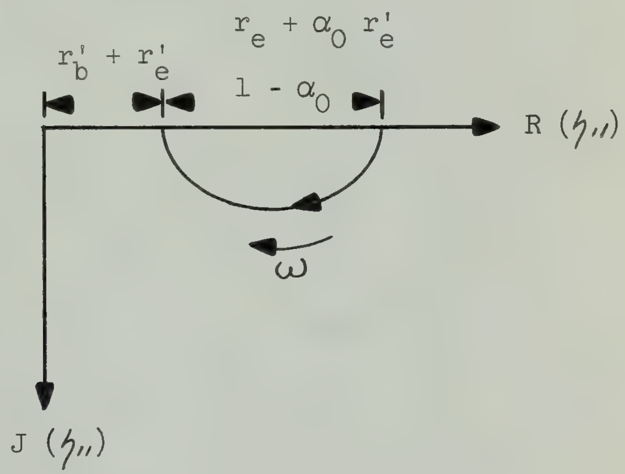


Figure 3

High Frequency Jig

Theoretically the measurement of h_{11} (S.C. Z_{in}) should yield the curve of Figure 4:



r_e - emitter junction resistance

r_e' - emitter contact resistance

r_b' - ohmic base resistance

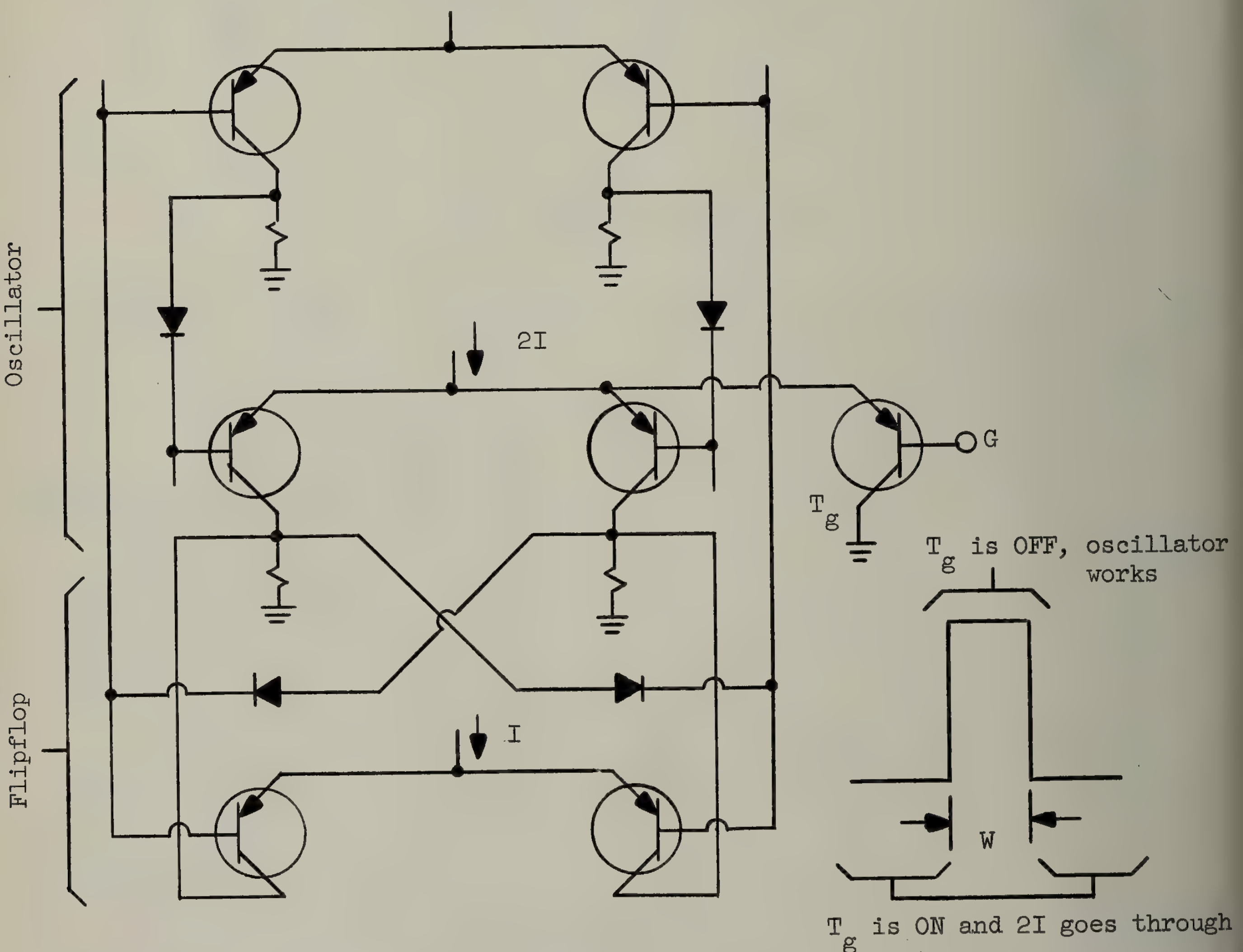
Figure 4

as a Function of Frequency

Evaluation of the jig showed fairly small parasitics. Measurements seem to be reliable to around 1000 mc. The theoretical curve and actual data show good agreement. In order to obtain $r_b' + r_e'$ frequencies in excess of 800 mc had to be used for the 2N250. This yielded at I_e = 10 ma, V_c = -5 v, $r_b' + r_e'$ = 51 . Dependence on both V_c and I_e is very small and will be considered in detail after some jig improvements.

4. Low Swing Counter Circuit

Making use of the flipflop which has been used in the two wire system, the counter circuit in Figure 5 is considered.



a) Circuit

Figure 5

Low Swing Counter

b) Timing

The circuit consists of an oscillator and a flipflop with a gate. Without the gate, the circuit would oscillate with its own characteristic frequency, setting the flipflop in each cycle if the flipflop can follow. If a triggering input has a pulse applied as shown in Figure 5b, the oscillator oscillates only within this pulse time. By adjusting the pulse width, W, such that the oscillator works only in a half cycle, the state of the flipflop changes once for each positive pulse. That is, for two pulses the flipflop completes one cycle: it works as a binary counter.

A preliminary experiment has been done with 10, 20, 40 mc. The circuit must now be studied with respect to the following two questions:

1) Requirement of a wave shaper in front of the circuit,
2) Whether or not the oscillator, which consists of two pairs of difference amplifiers, can be replaced by a pair of difference amplifier and delay lines.

5. <u>Diode Steering Counter</u>

The circuit shown in Figure 6 is the final binary configuration. The maximum repetition rate of the circuit is affected by the pulse shape and internal impedance of the driving source. For test, the only source available which had an appreciable repetition rate was a sine wave. The driver circuit shown in Figure 7 is used to shape the sine wave at 10 and 20 mc. At 40 mc, the circuit does not shape properly, but its output is essentially a sine wave. It does clip (although not sharply of course) so that the output pulses are more or less positive going sine wave half cycles. Using these circuits the flipflop triggers with a 10, 20, or 40 mc sine wave input. The amplitude sensitivity is somewhat frequency dependent and since the test source used was not adjustable, extensive amplitude sensitivity data is not available. Notice that the input to the driver is AC coupled and that the driver only responds to a negative going signal. The 43 Ω and 110 Ω input resistors are for attentuating

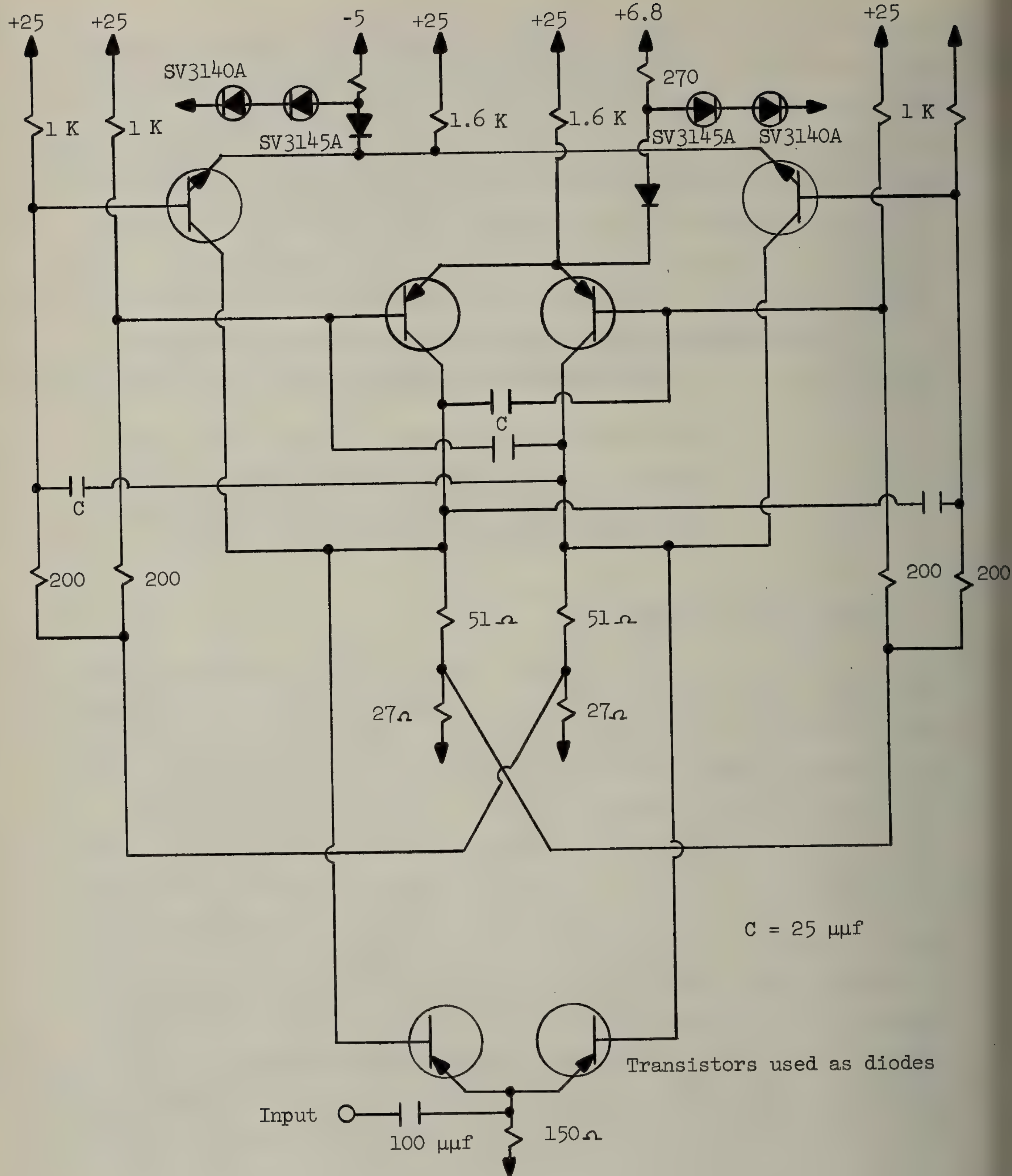


Figure 6

Binary Flipflop

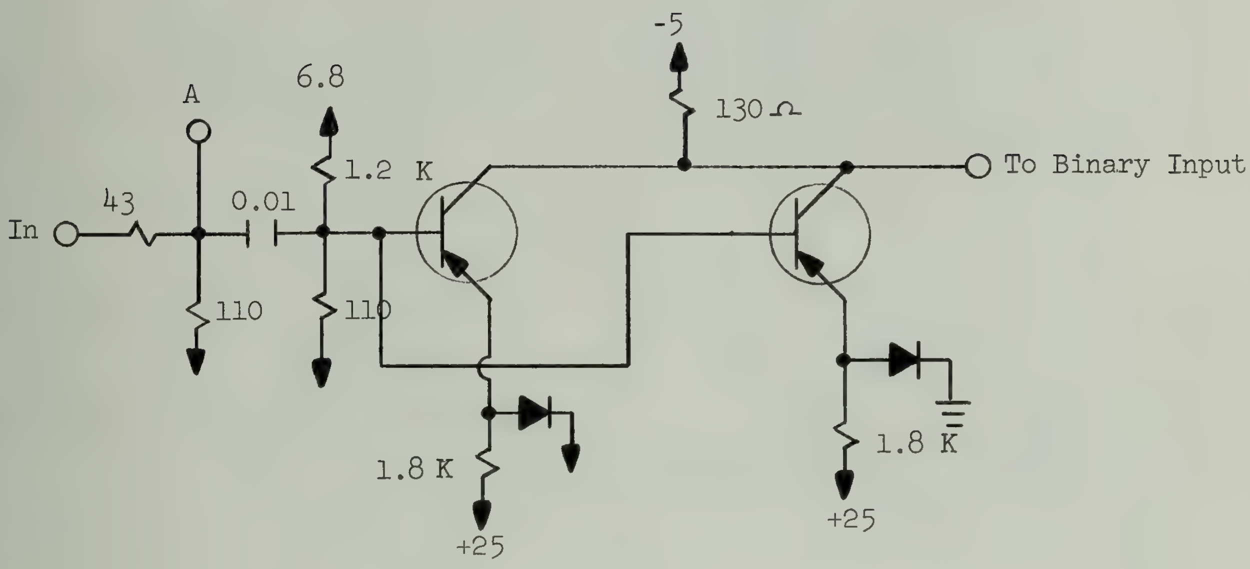


Figure 7

Driver

the input amplitude. Figure 8 shows the 40 mc input at point A in Figure 7. Figure 9 and Figure 10 are the collector waveforms. Figure 11 shows a 20 mc input at A and Figure 12 a collector output.

The binary input of the flipflop responds to a plus input swing and its sensitivity is 1.8 v positive swing from a 90 Ω source with a maximum rise time of 7-10 mμsec.

The npn transistors are Fairchild X1310's which are somewhat slower than the GF45011 pnp units.

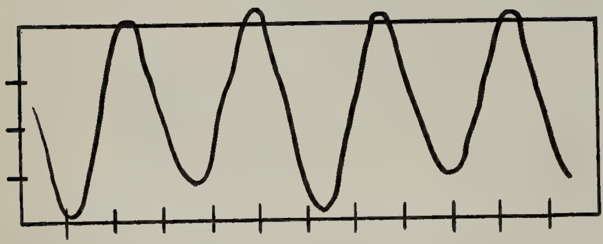


Figure 8
10 mμsec/cm   1 v/cm
Sine wave input (40 mc)
Point A in Figure 2

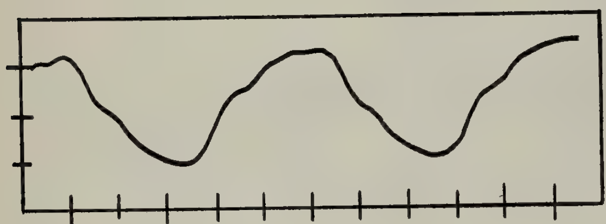


Figure 9
10 mμsec/cm   1 v/cm
Collector #1 output (Figure 1)

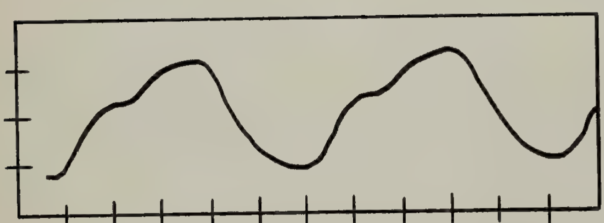


Figure 10
10 mμsec/cm   1 v/cm
Collector #2 output (Figure 1)

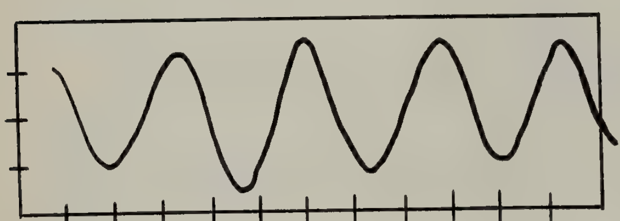


Figure 11
20 mμsec/cm   1 v/cm
Sine wave input (20 mc)
Point A in Figure 2

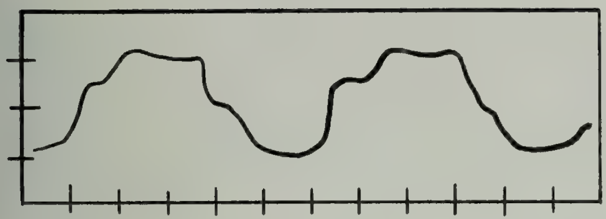
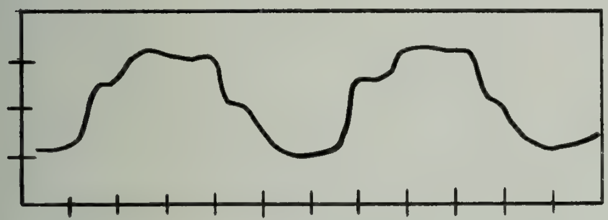


Figure 12

20 mμsec/cm 1 v/cm

Collector #2 (Figure 1)



Same as above

PART III

DATA REDUCTION METHODS

(Supported in part under Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

AUTOMATIC REDUCTION OF DATA FROM BUBBLE CHAMBER PHOTOGRAPHS

1. Rectangular Encodings of Bubble Chamber Negatives

File No. 377 (June 22, 1961) entitled "Minimal Redundancy Encoding of Bubble Chamber Negatives using Regular Rectangular Formats", by B. H. McCormick has been issued.

2. Hardware

Six 14 stage multiplier phototubes (RCA 7264) have been purchased. Appropriate housings and mounting brackets have been designed and subcontracted to Northern Tool and Die Company of Chicago.

A Micro-master 105 mm roll film camera with vacuum platten and automatic film advance, as well as a 105 mm enlarging head with automatic advance of sheet film holders have been ordered from Keuffel and Esser.

Facilities for making 105 mm diazo copies of Berkeley bubble chamber film have been purchased from the Tecnifax Corporation, Massachusetts along with 6 (350') rolls of diazo film.

Three rolls of Berkeley film have gratefully been loaned us by Luis W. Alvarez.

3. Artificial Patterns Reconstruction

The artificial pattern reconstruction routine of Shimamoto and McCormick has been completely rewritten to include facilities for

i) incorporation of pair count correlations, i.e.

$\chi^2 = \Sigma\,(N_\alpha - \bar{N}_\alpha)\;G_{\alpha\beta}\;(N_\beta - \bar{N}_\beta)$ as described earlier.

ii) search cell by cell of entire pattern for that cell which when flipped (i.e. black $\leftrightarrow$ white) most minimizes χ^2.

iii) final evaluation of strategies flipping 1, 2, 3, ..., n bits prior to selecting optimum strategy (equivalent to looking several moves ahead in checkers).

(M. Levitt, B. H. McCormick, F. Shimamoto, J. Stein)

PART IV

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of June, four new routines were added to the Illiac Library.

R 6 - 320 Fractional Power Routine (DOI or SADOI). This routine replaces the contents of the accumulator A by A^x. The binomial expansion for $(1+A-1)^x$ is used:

$$(1 + [A-1])^x = 2[1/2 + x(A-1)/2 + x(x-1)(A-1)^2/2.2! :...]$$
$$= 2[u_0 + u_1 + u_2 \ldots] \quad .$$

(D. J. Wheeler)

A 8 - 321 Multiple Precision Integer Subroutines (DOI or SADOI). This is a set of subroutines which will enable the user to perform simple computations on integers to full precision, without restricting the range of the integer variables to being less than 2^{39}. The set at present includes routines for addition, multiplication, shifting any number of binary digits left or right, output, small-integer output, and number transfer.

(John Ehrman)

KSL 5.52 - 322 Matrix Interleafer (SADOI Only). This routine augments a rectangular matrix A with another rectangular matrix B to form a final matrix C, which has $(n_A + n_B)$ columns and r_A rows. The elements of C may or may not have an N inserted after n_A characters, depending on a parameter. This feature may be utilized to prepare tapes for M13, M24, etc., where a row of a matrix terminated by an N must be augmented by a row of another matrix.

(John Ehrman)

KSL 5.55 - 325 Triangular matrix to square (or rectangular) SADOI Only. Symmetric matrices often are punched in triangular form. For some subsequent computer operation, however, a square matrix may be required. The purpose of this routine is merely to read a symmetric matrix in triangular form and to punch out the complete square matrix with N terminating symbols at the end of each row and a J at the end of the matrix.

An alternate use of this routine is to punch out only selected rows of the full square matrix.

(K. W. Dickman)

Illiac Usage

During the month of June, specifications were presented for 42 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 1958T. Numbers followed by T are for theses.

1958T Psychology. Hypnosis and Verbal Learning. This research involved the learning of verbal materials by subjects while in the normal waking state and also in the hypnotic or trance state. Sixty female undergraduates served as subjects, each learning one set of materials in the waking state and another, but similar, set of materials in the hypnotic state. The experimental conditions of hypnosis or waking state were counterbalanced across subjects. Three criterion scores were obtained for each subject in each session.

In addition to these scores, three premeasures for each subject were obtained. These measures concerned susceptibility to hypnosis, verbal ability and general anxiety level.

Illiac will be of use in this problem by providing all the necessary sums of squares and cross products needed for an analysis of variance and covariance treatment of the data. The use of the K-15 program will present the squares and cross products in such a way that covariance adjustments will be possible for any one or all three of the premeasures for any one or combination of the criterion measures.

Having this information will greatly facilitate the hand calculation of the appropriate statistical tests necessary to validate the psychological hypotheses.

1959 Chemistry. Analysis of Experimental Magnetic Resonance Data. The research problem is virtually the same as that for IBM 650 problem specification number 217'; that is, the analysis of certain experimental magnetic resonance data. However, in that case experimental values of chemical shifts or coupling constants (as a function of temperature) were fitted to a three-parameter theoretical expression. It has been discovered that certain data sets require the most general theoretical expression:

$$F(T) = \frac{a + be^{-\Delta E_1/RT} + ce^{-\Delta E_2/RT}}{1 + e^{-\Delta E_1/RT} + e^{-\Delta E_2/RT}} .$$

This involves five parameters: a, b, c, ΔE_1, ΔE_2. It is felt that the least-squares curve fitting process required, entailing a minimization with respect to five parameters in this case, would be most efficiently done on Illiac.

1960 Education. Factor Analysis of Sociometric Test Data. The purpose of the research is to analyze and compare the factorial structure of different classroom groups. The analyses and comparisons are made by the factor analysis. Two classes of Japanese high school students, which have different group structures, were selected as subjects for the experiment. The differences of the two experimental groups were observed in the number of subgroups which were present in the respective experimental groups.

Two 24 x 24 and two 22 x 22 sociometric matrices were obtained from the original data thus obtained from the two experimental groups. These matrices will be factor analyzed by using the rator-by-rator intercorrelations and the ratee-by-ratee intercorrelations. The rator-by-rator factor analyses will be done by means of Illiac routines: K-8 for intercorrelations, KSL 1.20 for Centroid Factor Analysis with Fixed Communalities, and KSL 1.80 for Varimax Rotation. The same output from KSL 1.20 will be also rotated by KSL 1.90 Oblimax Rotation. The ratee-by-ratee factor analyses will be done following the same procedures.

1961T Physics. Three-Body Kinematics. For the reaction $p + d \rightarrow p + p + n$, it is necessary to know the relation between the energies, momenta, and angles relative to the incident beam of all the final particles.

For an initial energy E, the Illiac will choose an energy E_1 and angles ϕ and Θ, and compute

$$V = \frac{1}{2}\sqrt{E}\ \cos\phi - \frac{1}{2}\sqrt{E_1}\ \cos(\Theta - \phi)$$

$$\omega = -1.1125 - E_1 + \sqrt{EE_1}\ \cos\Theta\ .$$

Then, if

$$\left.\begin{array}{l} V^2 + \omega < 0, \text{ there is no solution} \\ \omega > 0, \text{ there is one solution} \\ -V^2 < \omega < 0, \text{ there are two solutions} \end{array}\right\} \text{ for } E_2, \text{ where}$$

$\sqrt{E_2} = V \pm \sqrt{V^2 + \omega}$. Then, for each E_1 and E_2,

$$E_3 = E - (2.225 + E_1 + E_2)$$

$$\sin\psi = \frac{1}{\sqrt{E_3}}\left(\sqrt{E_2}\ \sin\phi - \sqrt{E_1}\ \sin\Theta\right).$$

Illiac will print tables of Θ, ϕ, E_1, E_2, E_3, $\sin\psi$ for given E and chosen values of Θ and ϕ.

1962T Psychology. Dimensions of Preference. The problem is an investigation of the number and types of factors used by college students in making occupational prestige and preference judgments. The K-8 routine will be used to obtain intercorrelations and intercovariances among 33 occupational preference and prestige variables for 4 groups of college students (N = 140 in each group). Also these variables will be intercorrelated with approximately 50 other variables.

The M-22 routine will be used to obtain eigenvectors and eigenvalues of a 50 x 50 matrix of intercovariances representing the responses of 280 subjects to 50 measures of preference.

1963 Mechanical and Industrial Engineering. Sample Size Estimation. The writer wishes to test by means of simulated sampling on the Illiac the reliability and relative superiority of two different formulae used to determine the required number of observations or samples necessary to make a selected statistical inference of a population mean value. The process will consist of taking prelim-

inary random samples of size n and applying sample means, variances and subgroup ranges as estimators in the determination of the ultimate sample size N' required. N' random samples will then be selected and mean values calculated.

It is desired to make comparisons of the distribution characteristics of sample sizes, N', required when using estimators of differing degrees of relative efficiency.

1964 Psychology. Oblimax Analysis of Socialization Practices. Samples of mothers from several different communities were interviewed concerning their child training practices. These data were factor analyzed and rotated using Oblimax rotation. The plots of the Oblimax factors against each other were reproduced on film strips. These film strips were examined and visual estimates of corrections of the rotations were made.

The present request is for computer time to correct the Oblimax rotation in accordance with the estimated corrections and print the new rotation on film for further examination.

These data were also rotated to orthogonal simple structure, using the Varimax rotation program. The present Oblimax analysis is being undertaken as a separate project in order to compare the results with the results of the Varimax rotation.

1965 Office of Instructional Television. Instructional Television. In general, most work will consist of analysis of covariance problems of non-orthogonal design. These problems are derived from studies on the effectiveness of television and use of students as leaders in the educational process. It employs the "Pyramid Method" wherein a senior professor supervises two graduate assistants, who in tern supervise senior undergraduates. The senior undergraduates are supervisors of peer leaders (freshmen and sophomores) who lead discussions in the dormatories, sororities and fraternities about the studies seen over television.

1966T Food Technology. The Development of Corn Carbohydrate Coatings for Control of Shrink and Preservation of Quality of Food Products. The variables involved in this problem are different formulated coatings of starch and algin applied to various food products such as frankfurters, eggs, green peppers, nuts,

etc. Other variables are storage conditions (temperature and relative humidity). An analysis of variance will be used for analysis.

1967 Animal Science. Effect of Various Levels of Fat on the Lysine Requirement of the Pig. In a series of three experiments, various energy levels (added fat) were added to rations to test the effect of the added energy on the lysine (amino acid) requirement of the pig.

Various levels of lysine were added to the various levels of energy. In so doing, gain (average daily gain) curves were resolved.

Illiac is to be used to determine the nature of the curves resulting from the various levels of lysine added to different levels of energy. Mathematically, a method of least squares is to be used to determine the lysine requirement from each of these curves.

1968T Physics. Auger Spectrum of a Σ^- in Emulsion. An experimental study which will determine the Auger spectrum of Σ^-, captured at rest in nuclear emulsions is nearly complete. It is now desired to compare this with theory.

The Σ^- should be captured in the vicinity of the K shell electron radius, corresponding to a principal quantum number of ~ 50. It then cascades down until it experiences nuclear capture. The number of Auger electrons ejected will depend on the ratio of the Auger transition probability to the radiative probability. For larger n values Auger transitions with $\Delta n = 1$ are most probable, especially for larger ℓ values. For smaller ℓ values, however, several radiative probabilities are of the same order of magnitude as the Auger probability. Since capture is expected to be predominant for intermediate ℓ values many transition probabilities are required. It is for this calculation that Illiac will be used.

1969 Illinois Geological Survey. Calculation of Covariance and Correlation Matrices. Trace elements occur in all argillaceous sediments. Within recent years evidence has accumulated that trace elements are useful to distinguish between marine and nonmarine muds and shales. For this study seven trace elements have been studied in some 66 samples to evaluate their effectiveness.

A discriminant function is to be used to classify the ancient samples in terms of the results gained from the study of the modern muds. Prior to

using the discriminant function, we wish to examine the stability of the correlation and covariance matrices in the different groups.

1970 Digital Computer Laboratory. Knight's Tours. A chess board consists of 64 cells, 8 x 8. The knight's move is two cells vertically and one cell horizontally, or vice versa. The question occurs: Can a knight be moved such that he covers all 64 squares of the board in just 64 moves? The answer is yes, and many mathematicians, including Euler, Roget, Warnsdorf, and Legendre, have studied this problem and devised systematic procedures for producing such tours. In general, however, their answers have been inadequate. In particular, very little work has been done with "symmetric" tours (i.e., when the knight's path is traced out, it leaves a symmetric pattern).

The field of Knight's Tours is a very broad one. Some of the problems are of current interest, and which we would like to investigate are listed below:

How many tours exist? Minding proposed a method of answering the question (Cambridge Mathematical Journal, Vol. 11, 1852), first raised by Legendre (Théorie des Nobbres, Vol. 2, page 165), but does not arrive at an answer because of "The almost unlimited extent of [the] calculation [which] leads to very many and very large numbers."

Verification of Warnsdorf's Rule. The German mathematician Warnsdorf gave a simple rule for moving the knight which leads to non-symmetrical, non-reëntrant solutions. Although no exceptions to the rule are known, its general validity is not yet verified.

Generation of Symmetric Tours. Perhaps the most elegant of all solutions are the symmetric, reëntrant solutions. Only three or four such tours have appeared in the literature, although a method is under study which, although not yet perfected, leads to symmetric solutions with a minimum of difficulty, and some twenty or thirty such solutions have been discovered. More experimentation in this area should prove extremely interesting, and might lead to an answer to the question: "How many closed, symmetric solutions exist?"

1971 Digital Computer Laboratory. Music-Braille Translation. Using existing equipment and methods, music scores will be input to Illiac. The musical notation will then be translated to Braille notation, and output in a code, not yet finalized, which will operate an automised Braille-writer.

It is hoped that this work will aid in a forthcoming, more difficult problem: English-to-Braille translation.

1972 Physics. Approximation of Complimentary Error Function. An approximation is desired for

$$\int_x^\infty e^{-t^2/2}\,dt \quad .$$

This function is asymptotic to

$$\sqrt{\pi/2}\ \frac{e^{-x^2/2}}{x} \quad .$$

Thus the suggested approximation is

$$e^{-x^2/2}\ \frac{p(x)}{q(x)}$$

where p and q are polynomials and the degree of q is one greater than the degree of p. This routine is required for the IBM 650 problem number 258'. Since the IBM 650 has 8 significant digits in the floating point mode, the greater accuracy of the Illiac will be useful to determine the coefficients of p(x) and q(x).

1973T Civil Engineering. Numerical Analysis of Cylindrical Shells and Space Frames. The problem is to find a numerical method for the analysis of cylindrical shell structures composed of a network of connected prismatic members. The solution of this system should be applicable to a shell composed of a continuous medium such as the reinforced concrete cylindrical shell or folded plate.

The problem entails establishing a set of linear algebraic simultaneous equations based upon the equilibrium and compatability relations for the model. The solution of these equations yields the various displacement components of the discrete points of the model which are then used to find the internal forces of the system.

This study has as its objective the development of the model. Three or four check problems are considered adequate to establish the validity of the model.

It is desired to use library routine L-7 to solve the 10 to 15 sets of simultaneous equations. Each set will consist of from 20 to 60 equations.

1974T Agricultural Economics. Coffee Demand Analysis. This problem is an investigation of the German imports of coffee, tea and cocoa. It requires the estimation of parameters of several supply and demand equations with annual quarterly observations. The estimations will be made by least squares and limited information methods.

1975 Theoretical and Applied Mechanics. Stresses Around Elliptical Flaws. The problem is to compute the stresses, both tension and compression, around the tip of elliptical flaws, varying the orientation of the ellipse and the ratio of major and minor axis of the ellipse from a circle to a very flat slit (a/b = 128). The results will form the basis for a probability distribution of flaw strengths, useful in estimating the influence of state of stress (including simple tension and compression) on fracture strength.

1976 Bureau of Economic and Business Research. An Explanation of the Saving-Income Ratio. The purpose of this study is to investigate the influence of interest rates on consumer saving behavior in a general multivariate regression model. Estimates of the parameters of variables which influence the ratio of saving to income for individual families will be calculated, and estimates are also needed of the associated standard errors of the regression coefficients.

Routine K-14 will be used to find these estimates for several repeated, experimental trials selecting different subsets of the independent variables.

1977T Sociology. D^2 Analysis of High School Students' Rankings of Ten Life Goals. One hundred high school students ranked a list of ten life goals in order of importance as they perceived them. Each student performed the ranking of the ten life goals on two separate occasions with approximately one month elapsed time between the two rankings.

The purpose of the analysis is to obtain a measure of agreement between the two sets of rankings for each student and, ultimately, to obtain some measure of test-retest reliability of the instrument.

KSL 2.70 will be used to obtain $\sqrt{D^2}$ for each student with regard to his first and second rankings of the ten life goals. Once $\sqrt{D^2}$ has been obtain-

ed, it will be possible to translate the D^2 value into a Spearman rank correlation coefficient without further computation.

1978 Coordinated Science Laboratory. Topological Analysis. When an electrical network is given, the solution (driving point or transfer function) can be obtained by the use of topological formulas. For this technique it is not necessary to supply numerical data for each component in the network. Instead the general property of the network can be studied. Some work on a limited case was done previously. It is proposed to extend this to analyze active networks.

1979 Bureau of Economic and Business Research. Some Applications of the Aggregate Production Function. The problem is to fit observed economic data to a production function by the least squares technique. The problem is complicated by intercorrelations among the variables, by serial correlation in the data, and by certain other inadequacies of the data. To overcome, or at least to minimize these difficulties, several transformations of the original function are being fitted. Only standard library routines are required.

1980 Marketing. Consumption Expenditure Study. This study involves an analysis of the functional relationship of six socio-economic variables to thirty-one expenditure variables. By factor analytic methods it is expected that patterns of relationship will emerge which will account for the major portion of the variance in the samples studied.

1981 Physics. Deuteron Compton Effect. This program will compute theoretical cross-sections for the elastic scattering of high energy photons by deuterons. The two formulas to be compared with experimental results are:

$$1.\quad \left(\frac{d\sigma}{d\Omega}\right)(\Theta) = \left(\frac{e^2}{M}\right)^2 \left(\frac{K_d}{K_e}\right)^2 S(q)\Big\{\frac{1}{2}(1+\cos^2\Theta)(|A^E|^2 + |A^M|^2) + \frac{1}{3}(3-\cos^2\Theta)(|B^E|^2+|B^M|^2)$$
$$+ \cos\Theta(|A^E+A^M)^2 - |A^E|^2-|A^M|^2) + \frac{2}{3}\cos\Theta(|B^E+B^M|^2-|B^E|^2-|B^M|^2)\Big\},$$

where Θ is the scattering angle, e, M, K_d, K_e, and q are physical parameters, and A^E, A^M, B^E, B^M are functions of eight further parameters.

2. $$\left(\frac{d\sigma}{d\Omega}\right)(\theta)=\left(\frac{e^2}{M}\right)^2\left(\frac{E_d}{E_d+K_d}\right)^2 S(q)\Big\{\frac{1}{2}|h_1|^2(1+\cos^2\theta)+\frac{1}{2}|h_2|^2(1-\cos^2\theta)^2+\frac{1}{3}|h_3|^2(3-\cos^2\theta)$$

$$+\cos\theta(1-\cos^2\theta)\left(-\mathrm{Re}\,h_1^*h_2+\frac{2}{3}\mathrm{Re}\,h_3^*h_4+4\mathrm{Re}\,h_5^*h_6-\frac{4}{3}\mathrm{Re}\,h_3^*h_5-\frac{4}{3}\mathrm{Re}\,h_4^*h_6\right)$$

$$-\frac{4}{3}\mathrm{Re}\,h_4^*h_5\cos^2\theta(1-\cos^2\theta)+\frac{2}{3}|h_5|^2(1-\cos^2\theta)(1+2\cos^2\theta)$$

$$+\frac{1}{3}|h_4|^2(1-\cos^4\theta)+\left(2|h_6|^2-\frac{8}{3}\mathrm{Re}\,h_3^*h_6\right)(1-\cos^2\theta)\Big\}\ ,$$

where M, e, E_d, K_d, q, θ are physical variables, and h_1, h_2, h_3, h_4, h_5, h_6 are complex functions of nine further parameters.

1982 Coordinated Science Laboratory. Uniformly Smoothed Phase (USP). The process of uniformly weighted smoothing is applied to the sequence representing signal mixed with noise in the output of a phase-difference detector. The phase difference sequence results from differencing the arctangents of ratios of terms in a pair of sequences derived by exponential smoothing in sequences of independent normal random variables. The results are used for parameter estimation in predicted distributions and for estimation of detection probabilities.

1983 Psychology. New Rotoplot. In order to investigate the properties of a new routine designed to replace KSL 1.96 and in addition to codechecking this routine, computer time is requested. This routine will accept up to 40 factors and over 100 variables. Several procedures will be combined so that the new routine will calculate the correlations among the factors, perform the transformation to a new set of axes, list the hyperplane counts, and finally photograph the factor plots. To accomplish this on a large matrix requires more than the usually allotted time for program checks.

1984 Mining and Metallurgical Engineering. Diffusionless Phase Transformation. This study is a continuation of IBM 650 problem number 244'. The problem is essentially one of determining if the mathematical model of diffusionless phase transformations gives results equal to or in accord with the experiment results. The magnitude of the shear is represented by a 3 x 3 non-symmetric matrix $\emptyset$. P is a diagonal strain matrix.

The Illiac portion of the problem is concerned with evaluating the roots of a large number (about 200) of determinants, $|\phi P - \lambda I|$, using J-3 and then finding the eigenvectors using L-3.

1985T Civil Engineering. Influence Surfaces for Continuous Slabs. This thesis problem is concerned with the study of moments and shears in continuous slabs due to concentrated loads. The study will be made using influence surfaces. The influence surfaces will be plotted from influence coefficients computed by the Illiac using a distribution procedure coded by A. Ang. This program is available in the Civil Engineering Department. This latter program requires that fixed end moments and reactions be computed first. These quantities will be obtained using finite difference equations which will be solved using library routine L7-230.

1986 Institute of Labor and Industrial Relations. Leich Electric Analysis. The purpose of this request is to determine the interrelationships among a set of productivity ratios for individual employees of the Leich Electric industrial firm. Pertinent variables include age, tenure, education and degree of satisfaction with job related elements.

1987 Institute of Labor and Industrial Relations. State Police Analysis. This request is to determine the intercorrelations of a set of variables measuring perception of mobility potential for state troopers. Pertinent variables include age, tenure, education, and degree of satisfaction with 31 job related elements.

1988T Agricultural Economics. Analysis of Supply Functions. The problem is concerned with the estimation of supply functions for milk in the Chicago milkshed. Two different estimating procedures will be used:

(1) Regression analysis to estimate the parameters of relevant production functions; and

(2) Linear programming analysis with price mapping to estimate optimal supply functions.

1989 Sociology. Log-normal Confidence Limits. A problem of casualty actuarial science is that of determining the number of individuals (policy holders) needed to assure a desired level of stability in premium rates. It has been demonstrated recently that the probability density function for claims' costs, of several types, is log-normal; i.e., the logarithms of costs are distributed normally. What is needed for this problem are the confidence limits for the average cost of a group of claims. At the present time no one has been able to derive the function mathematically. Yet these limits could be determined empirically if a large number of samples of a log-normal distribution were to be generated.

This particular study undertakes to investigate the "goodness" of an approximate method for finding confidence limits by generating a number of samples of a particular size and plotting the distribution of the average cost for each sample. This distribution will then be compared with the approximate methods predictions.

1990T Electrical Engineering. Integral Electron Density. The program for this study calculates the following integrals:

$$\int_T^R N dL, \int_T^R N^2 dL, \ldots \int_T^R N^m dL \quad ,$$

T and R are the positions of satellite and receiving station, N is the electron density present at each point according to a given ionosphere model, dL is an element of the straight line that joins T and R, and m is a given integer. This program involves the parametric expression of a straight line in geographic coordinates (latitude, longitude and height) with N as a function of geographic coordinates and a Simpson integral.

1991T Agronomy. Shading Corn Hybrids. Five different levels of shade (30, 60, 70, 80, and 90%) were used on two different corn hybrids. The plants were also shaded on three different days. Data with these treatment combinations consists of measures of grain yield, plant height, ear height, days until one-half silk, length of ear, diameter of ear, etc. The method of analysis of variance will be used to determine if there are significant differences between treatments.

1992 Bureau of Economic and Business Research. Adjustment of Survey Data for Non-Sampling Errors. Reports of asset holdings were obtained from selected panel members. The nature of the research problem is to derive regression functions from the data to detect non-reported assets. To do this it is desirable to include in the sample those panel members who did not submit to an interview. Then the regression functions would then be used to estimate asset holdings of these panel members in order that they may be included as part of the total sample.

1993 Electrical Engineering. Synthesis of Antenna Impedance Matching Networks. This research is concerned with a design of a non-positive reel driving point impedance function using one negative impedance converter and RC networks. The driving point function is a ratio of fourth degree polynomials. The method employed is to use surplus factors. In general this results in a higher degree polynomial whose roots must be determined. Illiac is being used to determine roots of the polynomial of 7th degree which has resulted from the assumed impedance of rank 4.

1994T Theoretical and Applied Mechanics. Large Deflections of a Plate Strip. Library routine J-2 will be used to solve a large number of cubic equations. Some of the real roots of these equations are coefficients of the polynomial representations for the displacements of the plate strip.

1995 Coordinated Science Laboratory. Program Development. A method for the direct integration of $y'' = f(x,y)$, developed by Professor A. T. Nordsieck, will be investigated and compared with other procedures for the integration of y''.

1996T Civil Engineering. Plastic Analysis of Orthogonal Grid. In this analysis an upper bound on the collapse mechanism can be determined by varying the orthogonal grid configuration. Then an iterative procedure involving equilibrium relations will be used to converge to the point at which collapse occurs.

1997 Electrical Engineering. Cat Temperature Study. A thermal equivalent circuit for a cat and heat exchanger is used to permit the writing of a set of differential equations relating cat brain temperature and heat exchanger water temperature. The program combines these equations with those for various types of controllers under consideration and solves for the transient response of the system. The desired result is a set of controller parameters which will produce a stable equilibrium in the shortest time.

1998T Structural Research. Slabs with Cantilevered Edges. The problem is to determine the effects of different widths of cantilevered edges, beam rigidities and column stiffnesses, on the intensity and distribution of bending moments in a slab. The computer will be used to solve the matrices obtained by application of finite difference equations.

1999T Elementary Education. Comparison of Two Different Student Teaching Groups. An instrument to measure perceptions of teacher tasks consisting of 140 items was administered to two groups of 19 subjects. Given the total score matrix S_{38x140}, it is desired to approximate this by $\hat{S}$ where $\hat{S} = U_r G_r W_r$. Both U_r and G_r can be determined by finding the roots and vectors of SS', since $\hat{S}\hat{S}' = U_r G_r W_r W_r' G_r U_r' = U_r \lambda_r U_r'$. Finally a discriminant function analysis will determine whether an effective separation between groups can be made on the basis of the parameters describing the subjects.

Table I shows the distribution of Illiac machine time for the month of June.

TABLE I

	Hrs:Min	
Scheduled Engineering	61:22	
Unscheduled Engineering	7:32	
Drum Test	5:40	
Leapfrog	4:16	
R. A. R.	:15	
Library Development	8:49	
Classes	3:12	
Instruction	:05	
Demonstrations	3:14	
		94:24

Use by Departments

	Hrs:Min
Administration	:30
Agricultural Economics (47 15 05 334)	:17
Agricultural Economics	14:56
Agronomy (00 15 65 330 38)	2:04
Agronomy (00 15 15 306)	2:45
Agronomy	2:03
Animal Science	5:54
Astronomy (NSF G-14834)	2:07
Bureau of Community Planning (84 16 383)	4:02
Bureau of Economic and Business Research	1:37
Bureau of Educational Research (PH M1839)	:33
Bureau of Educational Research	4:09
Chemistry (NSF G-5907)	:45
Chemistry	54:55
Civil Engineering (NSF G-6572)	:23
Civil Engineering (AASHO ROAD TEST)	9:14
Civil Engineering	114:06
College of Medicine	3:37
Coordinated Science Lab. (DA-36-039-SC56695)	69:56
Digital Computer Laboratory (US TR AEC-1018)	13:21
Digital Computer Laboratory (AEC AT(11-1)415)	17:44
Digital Computer Laboratory (Nonr 1834(27))	:01
Digital Computer Laboratory	:49
Economics (NSFG 7056)	7:46
Economics	:06
Education	:35
Electrical Engineering (AF 33(616)6079)	:03
Electrical Engineering (Nonr 1834(22))	1:23
Electrical Engineering (NASA-NSG 24-59)	3:20
Electrical Engineering (NOBSR 64723)	4:04
Electrical Engineering (Nonr 1834(02))	3:18
Electrical Engineering (AF 7043)	3:00
Electrical Engineering (AF 4622-25-314)	1:10
Electrical Engineering (SL 85173)	:26
Electrical Engineering	10:14
Finance (IHR-71)	:06
Food Technology (50-343)	1:51
Geological Survey	1:01
Inst. of Communications Res. (44-28-20-378)	8:37
Inst. of Communications Res. (USPHM-3941)	3:52
Institute of Communications Research	6:05
Inst. of Labor and Indus. Rela. (00 6010 300)	1:49
Inst. for Res. on Excep. Ch. (HE and W SAE8204)	:51
Inst. for Res. on Excep. Ch. (IREC)	1:33
Inst. for Research on Exceptional Children	:12
Marketing	:29
Mathematics	13:49
Mechanical Engineering	:56

(cont'd.)

Use by Departments
(cont'd.)

	Hrs:Min		
Mining and Metallurgical Eng. (AF 420)	:24		
Mining and Metallurgical Eng. (CML 51F)	1:11		
Mining and Metallurgical Eng. (TRUS AF6770)	:32		
Mining and Metallurgical Engineering	1:44		
Music	2:41		
Natural History Survey	:04		
Office of Instructional Television	:24		
Petroleum Engineering	5:04		
Physics (Nonr 1834(05)A)	23:56		
Physics	16:10		
Psychology (MD 2060)	1:28		
Psychology (M-1733)	3:18		
Psychology (1715)	:38		
Psychology (ONR 46-32-66-362)	3:41		
Psychology	96:09		
Sociology	1:14		
State Water Survey (DA-36-039-SC75055)	6:55		
State Water Survey	1:45		
Theoretical and Applied Mechanics (NOBS 72069)	:28		
Theoretical and Appl. Mech. (DA-11-070-508 ORD)	4:52		
Theoretical and Applied Mechanics	2:09		
Veterinary Physiology	:04		
Williams College	9:21		
		586:36	
			681:00

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This

table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Reader	1
Control	1
Power Supplies	3
Drum	5
Unknown	1
Total	11

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/1/61	20:15	:07	3:38	1	(1) Drum - bad solder joint on Pre-amplifier chassis	:00	:00	0
6/2/61	21:20	:00	2:40	0		:00	:10	0
6/5/61	21:09	:00	2:51	0		:00	:07	0
6/6/61	20:51	:16	2:53	1	(1) Filament voltages low	:00	:06	0
6/7/61	21:18	:25	2:17	1	(1) Drum failure	:00	:06	0
6/8/61	21:35	:00	2:25	0		:00	:55	0
6/9/61	21:33	:00	2:27	0		:00	:05	0
6/10/61	21:50	2:10	:00	1	(1) 2,000 v. power supply out	:00	:00	0
6/11/61	24:00	:00	:00	0		:00	:20	0
6/12/61	17:57	2:33	3:30	1	(1) -2,000 v. power supply unstable	:00	:20	0
6/13/61	20:41	:07	3:12	1	(1) Reader "B" failed	:00	:00	0
6/14/61	20:30	:00	3:30	0		:00	:00	0
6/15/61	21:17	:00	2:43	0		:00	:00	0
6/16/61	22:45	:00	1:15	0		:00	:25	0
6/17/61	24:00	:00	:00	0		:00	:08	0
6/18/61	24:00	:00	:00	0		:00	:27	0
6/19/61	21:04	:00	2:56	0		:00	:07	0
6/20/61	20:56	:00	3:04	0		:00	:00	0
6/21/61	20:10	:26	3:24	3	(1-3) Drum failed, no reason found	:00	:00	0
6/22/61	19:39	1:15	3:06	1	(1) Machine slowed down, replaced tube in G.G. chassis. Seemed normal.	:00	:15	0
6/23/61	21:20	:00	2:40	0		:00	:00	0
6/24/61	24:00	:00	:00	0		:00	:12	0

(cont'd.)

TABLE III (cont'd.)

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/25/61	24:00	:00	:00	0		:00	:22	0
6/26/61	21:13	:14	2:33	1	(1) Unknown	:00	:02	0
6/27/61	21:26	:00	2:24	0		:00	:00	0
6/28/61	21:17	:00	2:43	0		:00	:09	0
6/29/61	21:06	:00	2:54	0		:00	:00	0
6/30/61	21:43	:00	2:17	0		:00	:00	0
TOTALS	603:05	7:33	61:22	11		:00	4:16	0

PART V

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New International Business Machines 650 Codes

During the month of June, no new 650 routines were added to the International Business Machines 650 Library; however one 650 routine was revised.

K4' - 63' **Analysis of Variance by Method of Fitting of Constants.** This program performs the computations required for a general class of statistical procedures called analysis of variance and covariance. A set of observations may be expressed in matrix form,

$$Y = X B + E ,$$

where Y is a set of observed dependent variables, X expresses the relations of the observed measures to the treatments administered, and E is a matrix of errors.

A least squares estimate of the B weights is,

$$\hat{B} = (X'X)^{-1} X'Y .$$

The total sums of squares for the y's is Y'Y, and the sums of squares accounted for by the estimates of the b's is $\hat{B}' X' Y$. Then the error sums of squares is found by subtraction as follows:

$$SS_e \quad Y'Y - \hat{B}' X' Y .$$

Similarly, under the null hypothesis, the sums of squares accounted for by the b_o's is as follows:

$$SS_{B_o} = \hat{B}_o' X_o' Y .$$

The F ratio then is:

$$F = \frac{(\hat{B}' X' Y - \hat{B}_o' X_o Y)/df_b}{SS_e/df_e} .$$

The $b_j \neq 0$ if F is significant at the chosen level.

This program supplies all of the ingredients for the calculation of F.

(M. A. Fisherkeller and M. T. Gray)

International Business Machines 650 Usage

During the month of June, specifications were presented for 22 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 264'. Numbers followed by T are for theses.

264' Marketing. A Study of Consumption Expenditures of Farm Families. This problem involves the classification of expenditures into various family characteristics - income, family size, education, age, occupation, and geographic location.

Calculations are needed to determine means for each expenditure, and percentages of these means to the total mean expenditure for each classification.

The data are classified also by state and five districts. Identical calculations are to be made for each.

265' Bureau of Economic and Business Research. Small Retailer Survival. A two year research project on the "Industrial, Community, and Internal Conditions of Small Retailer Survival" is currently being carried out.

It is proposed to make a Chi-square analysis of retail establishments classified by employment size, by economic structure, and population of the cities in which they are located. The purpose is to determine, for each kind of retailing, whether variations in size of retail establishments (measured by number of employees) are associated with differences in the economic structure of the cities in which the establishments are located. If such an association is found, the results would provide new knowledge about the market structure of the various kinds of retailing and would be useful in providing a guide to the most favorable type of city for the location of small retail

establishments, which is the principal concern of the larger study. The analysis would be carried through for 40 different kinds of retailing, utilizing two by five and two by forty tables for firms measured in terms of employee size. For firms measured in terms of volume of annual sales, two by nine and two by forty tables will be required. Values will be computed for each of nine distinctive community types, in an attempt to identify those lines and sizes which are particularly successful or unsuccessful in a given community setting.

As far as can be determined, no attempt has been made to determine whether variations in size of retail establishments are associated with differences in the economic structure of cities. In this project, the relationship between size of retail establishment and certain other characteristics of their locations is to be studied. Since the published data are not presented in sufficient detail to permit an analysis in terms of economic structure of cities, special tabulations of data from the U. S. Bureau of the Census will be obtained and used.

226' Sociology. Models of Rational Choice Behavior. This study is based on a national probability sample of 2,674 medical students in the continental United States. It involves the development and testing of a number of mathematical models of choice of medical specialty. To the extent that the models can predict the actual choices of medical students, rationality of choice behavior will be demonstrated. An analysis will be made of the various characteristics of students with different degrees of rationality.

The chief relevance for sociology is the contribution to the literature on mathematical models (mainly variations of summated difference-scores) in sociology. The emphasis is on working with variables of considerable theoretical importance (values and expectations of the opportunities for fulfilling values in the various specialties) rather than developing models primarily aimed at prediction for immediate applied purposes.

267' Psychology. Role Conflict Study. The problem requires computation of a large number of analysis of variance for a 4 x 4 factorial design having 5 cases per cell. Results of this analysis will permit assessment of effects of different group roles, from problem sequences, and their interaction on interpersonal perception, adjustment, and team effectiveness scores.

268'T Civil Engineering. Properties of Reinforced Concrete Section at Crushing. The problem is to determine the unit curvature, ϕ, which will satisfy static equilibrium at the section using the known properties of steel and concrete used. For this phase of the problem the concrete is assumed to crush at a specified strain, ϵ_c, and ϕ is varied until equilibrium is obtained. About 45 different sections are to be analyzed at this stage.

269' Chemistry. Non-Intersecting Random Walk Studies. The purpose of this program is to process data obtained in the study of a non-self-intersecting random walk model of a polymeric system. The input data is taken from results obtained on the Illiac and consists essentially of the quantities: R_i^2, the squared end-to-end distance of random walk i; ν_i, the number of nearest neighbor contacts in walk i; ω_i, a weighting factor expressing the relative probability of configuration i; and ξ_j, a dimensionless parameter essentially equal to an energy divided by kT (Boltzmann constant times temperature). Quantities calculated by this program include:

$$< R_j^2 > = \frac{1}{Q_i} \Sigma_i \ \omega_i \ R_i^2 \ e^{\nu_i \xi_j} \qquad\qquad < \nu > = \frac{1}{Q_i} \Sigma_i \ \omega_i \ \nu_i \ e^{\nu_i \xi_j}$$

$$Q_i = \Sigma_i \ e^{\nu_i \xi_j} \ \omega_i$$

and the respective standard deviations.

270'T Psychology. Moral Judgments and Neurosis. This thesis research is concerned with the relationship of moral judgments to psychoneurosis. On the basis of Freud's theory that neurotics have severe and rigid superegos, it is predicted that they will obtain higher scores than normal people on a "Moral Judgments Inventory" which has been constructed to indicate superego functioning. From Mowrer's theory which holds that neurotics have a weak and unassimilated superego, the opposite prediction is made. A third and integrating view is proposed which holds that some neurotics may have very weak superegos, while other neurotics may have very strong ones, and that the direction and intensity and consistency of this deviation will be related to certain neurotic syndromes and personality variables.

T-tests will be used to compare two male groups, that is, 100 neurotics and 175 normals (the latter being defined as men without a history of psychiatric

or psychological treatment) with regard to Moral Judgments scores (total as well as part scores). The T-test is to be applied to see if neurotics and normals differ in their variability around their group, as well as around their individual average. Correlational methods are to be used to determine to what degree neuroticism, in general, specific aspects of neuroticism, and other variables relate to moral judgments.

Since the various instinctual needs and demands of socialization are integrated in personality development and assumed to result in different personality types and superego functions, a factor analysis of persons is planned. About 50 persons with scores on 51 items will be the basis for a cross-products matrix. A subject's score on each item will be multiplied by the corresponding score of another subject and an "average cross-products" score obtained by dividing by 51. Such cross products (average) will be computed between all possible combinations of the 50 persons yielding a matrix of 50 by 50 persons. The factor analysis will be performed on this matrix to determine whether dimensions of persons can be ascertained and if so, what characteristics differentiate them.

Product moment and T-test routines are to be used.

271'T Theoretical and Applied Mechanics. General Inelastic Buckling Solution. The problem of inelastic buckling of eccentrically-loaded columns requires trial and error solutions. The method to be used is to divide the column into 40 segments and analyze each segment individually. By progressing along the column length, the behavior of each segment is analyzed and the boundary conditions are examined. If the conditions are not satisfied the load on the column is adjusted and the solution repeated.

272' Sociology. Adjustment of the Aged. The study represents an investigation of a variety of factors related to the health and adjustment of the aged. The theoretical framework involves two major sets of independent variables: (1) role changes, and (2) lack of value fulfillment, in each of five areas (family life, work, housing, recreation, and relations with physicians).

The computer aspect of the analysis involves the combining of item-pairs into corresponding d scores. These will be combined into sets, one for

each of the five areas (family life, work, etc.), and these sets will then be summated in four different ways. Each method of summation corresponds to a different hypothesis concerning processes affecting the adjustment of the aged. The sums will then be utilized as independent variables in a correlational analysis of the adjustment of the aged, involving 20-25 variables.

273' Physics. The Functions of Born Approximation Curves. IBM 650 time is requested to plot functions of the form:

$$f(x) = C_1 \left(\frac{\sin x - x \cos x}{x^3}\right)^2, \quad 0 \leq x \leq C_2$$

bound to have at the origin the value $f(0) = \frac{C_1}{g}$ and a first zero at $x_0 = 4.493$. Eight different sets of parameters will be used for C_1, C_2.

274' Institute for Research on Exceptional Children. Special Class Project. Various intelligence and achievement tests were administered to two groups of mentally retarded children. There are twenty-four test scores for each of one hundred subjects. Group 1 has fifty-one children and group 2 has forty-nine children. Means, standard deviations, and intercorrelations are to be computed for each set of these data.

275'T Chemistry. Structure Determination of N-Benzyl Pyrol. The problem is to determine the crystal structure of N-benzyl-pyrol using the usual crystallographic procedures. The structure is of interest because of the very large amount of thermal motion exhibited by the molecule. A study of the structure at various temperatures down to and including liquid nitrogen temperatures is contemplated.

The 650 is to be used in the calculation of the electron densities within the unit cell and in the calculation of the structure factors.

276' Chemistry. Structure Determination of $Cu(diam)_2(ClO_4)_2$. The compound $Cu(diam)_2(ClO_4)_2$ has a structure change which occurs at 44°C.

The usual crystallographic calculations of electron densities using Fourier techniques and structure factor calculations are to be carried out on the 650 in order to determine the nature of this change.

277' Marketing. Business Management Game. Graduate students enrolled in Marketing 422 and Management 402 will be given some extra curricular experience with business games this summer. There are twelve students in these two sections of our graduate program which would permit us to form three teams of four students. We would arrange for the students to participate at hours other than the regular meeting periods of these two courses and at a time that will be mutually convenient for the instructors, students, and time available for the IBM 650 equipment.

The program to be used is the IBM Business Management Game.

278'T Psychology. The Perception of Significant Persons by Indian and American Males. The present problem is a cross cultural study investigating whether differences exist in the interpersonal perceptions of Indian and American subjects. The study concentrates on the perception of primary persons; e.g., the self, mother, father, wife, etc. The hypotheses formulated are concerned with whether there are statistically significant differences between the samples in:

a) the degree to which the person described by the subject is esteemed; and

b) the perceived similarity or discrepancy in a subject's perception of two people.

Our investigations at present seem to indicate that measures of interpersonal perception may operate in a different manner when applied outside the American culture. Correlations will be computed to determine the relationship between the esteem scores and the similarity scores of the subjects in the two cultural groups.

279' Chemistry. Calculation of Formation Constants. The research is concerned with the calculation of formation constants K_1, K_2, K_3, respectively, for the coordination-compound equilibria, $M + Ch^- \quad MCh$; $MCh + Ch^- \quad MCh_2$; $MCh_2 + Ch^- \quad MCh_3$; where Ch^- is the anion of a weak acid. The calculation involves the evaluation of the Bjerrum formation function using potentiometric-titration data.

Calculations involving all possible combinations of the selected titration data are essential to the evaluation of the most reliable K_n values for a given titration.

280' Civil Engineering. Modal Analysis for Doubly-Curved Shells. The purpose of this study is to investigate various theories of analysis of doubly-curved thin shells. Both membrane and flexural theories will be studied as well as the boundary conditions.

281' Dairy Science. Relations Between Age of Dairy Bulls and Their Semen Characteristics. Data were obtained from semen samples collected between 1949 and 1959, from the five breeds of dairy bulls housed on the University Dairy Farms. The data includes only those samples obtained from bulls maintained on an *ad libitum* feeding program during their reproductive life.

The relations between the age of the bulls and their semen characteristics within certain frequencies of semen collection are to be computed.

The resulting statistics will be used to determine the effects of advancing age and frequency of collection on semen quantity and quality. In addition, these statistics will be compared with those already computed for bulls fed on the controlled total digestible energy intake (TDN) program. By this means it may be possible to demonstrate an influence of energy intake on the semen producing capacity of mature bulls as well as the optimum frequency of collection for maximal semen production in a given period of time.

282' City Planning and Landscape Architecture. Traffic Linkage Patterns. Several ratings were obtained on the attractiveness of a number of communities in Illinois. The number of vehicle trips on highways leading into these communities also was counted. Correlations, first order and also multiple, will be computed showing the interrelations between attractiveness and traffic.

283'T Theoretical and Applied Mechanics. Solution of Non-linear Algebraic System. The thesis problem to be solved is the creep torsion of non-circular bars. An approximation technique is used to solve the resulting differential equation. This leads to systems of non-linear algebraic equations for which a high-speed computer is required.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of June.

TABLE I'

		Hrs:Min	
Scheduled Engineering		16:07	
Unscheduled Engineering		19:36	
Air Conditioning		5:55	
Tape Testing		:47	
Agronomy Library		:21	
DCL Library		14:05	
SSU Library		2:58	
Classes		:13	
CE 391	:13		
Instruction		1:45	
Demonstration		:19	
Wasted		5:13	
			67:19

Use by Departments

Agronomy		:28
Astronomy		7:54
Chemistry		9:31
Civil Engineering		25:23
Digital Computer Laboratory		:43
Electrical Engineering		2:13
Graduate College		13:15
Mechanical Engineering		5:10
Mining and Metallurgical Engineering		4:30
Physics		8:19
Psychology		6:47
Small Homes Council		1:23
State Water Survey		19:48
Statistical Service Unit		185:06
Admissions and Records	28:02	
Agricultural Economics	21:45	
Bur. of Business Management	:16	
Bur. of Ec. and Bus. Res.	:40	
Bur. of Educational Res.	4:26	
Bur. of Institutional Res.	1:16	
Bursar's Office	6:39	
Business Office	18:38	
Civil Engineering	6:35	
Dairy Science	1:05	
DHIA	38:00	
Education	9:04	
Finance	:30	
Forestry	1:55	
Marketing	13:27	

(cont'd.)

Use by Departments

(cont'd.)

		Hrs:Min		
Natural History Survey	:45			
Navy Pier	4:20			
Psychology	11:20			
Sociology	2:22			
Statistical Service Unit	3:18			
Student Counseling Service	10:43			
Theoretical and Applied Mechanics		1:15		
			291:45	
				359:04

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for June.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

Air conditioning		1
Basement unit had oil leak	1	
407 accounting machine		3
Prints incorrectly	3	
533 card read punch		14
Refuses to feed cards	2	
Card jam	6	
Fuse blew	1	
Reads incorrectly	3	
Punches incorrectly	1	
False end of file lights	1	
650 console and magnetic drum		4
Switch not resetting circuits	1	
False fuse light	1	
Lost bits	1	
Accumulator circuit	1	

(cont'd.)

TABLE II'
(cont'd.)

653 high speed storage, floating point, index register		6
False storage unit lights	5	
Storage unit error of some kind	1	
655 power unit		1
Fuse blew	1	
727 and 652 tape units and tape control		3
Read error	2	
Unit would not unload	1	
	TOTAL	32

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
6/1/61	15:32			:07	0		
6/2/61	15:35			:11	1		(1) Card jam in 533 read. Removed.
6/5/61	11:34	3:53	:33		1		(1) Program reset does not clear out storage selection checking light. Bad switch found.
6/6/61	14:53		:34	:31	2		(1) False fuse light. (2) Position 9 of word 1 on 407 does not always print when it's 0.
6/7/61	15:50			:28	0		
6/8/61	15:41			:33	0		
6/9/61	15:50			:12	1		(1) Read error from tape.
6/12/61	12:41	4:00			0		
6/13/61	16:16		1:51	:10	2		(1) 407 not printing on line. Dirty circuit breaker. (2) False storage unit light
6/14/61	14:01		1:46	:11	2		(1) Lost a quinary bit in position 2 of the distributor. (2) Fuse blew in 533 due to a loose screw in board.
6/15/61	10:09			:11	2	5:55	(1) Oil leak in air conditioning unit in basement. (2) 407 not printing 0's at random.
6/16/61	6:40		9:09	:17	1		(1) Trouble in reading tape. Reason never found and it seems to have disappeared.
6/17/61	4:53			:30	0		
6/19/61	10:52	4:30	:34		2		(1) Col. 22 is not punching on 533. Bad tube found in 655. (2) Card jam in 533 punch.
					(cont'd.)		

TABLE III' (cont'd.)

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
6/20/61	13:59		:36	:26	4		(1) False end of file lights on 533 (2) Storage unit errors of some kind. (3)Card jam in 533 punch. (4) 533 won't feed cards loose screw found.
6/21/61	14:24		:65	:31	3		(1) False storage unit lights. (2) Storage selection errors due to improperly reading card. (3) Card jam in 533.
6/22/61	14:29		:20	:10	6		(1) False storage unit lights. (2)(3)Cards read incorrectly. (4)(5) Card jam in 533 punch. (6) 533 would not feed cards. Broken screw and wire found.
6/23/61	14:26		1:25	:05	0		
6/26/61	12:18	3:44			0		
6/27/61	15:55			:05	0		
6/28/61	14:47		:61	:20	1		(1) Accumular checking light on. Bad tube found.
6/29/61	16:24			:05	2		(1) False storage unit light. (2) Tape unit 2 would not unload. Found blown fuse.
6/30/61	15:04		:42	:10	2		(1) Fuse blew in power supply. (2) False storage unit lights.
TOTALS	312:13	16:07	19:36	5:13	32	5:55	

PART VI

GENERAL LABORATORY INFORMATION

Personnel

The number of people associated with the laboratory in various capacities is given in the following table:

	Full-Time	Part-Time	Full-Time Equivalent
Faculty	11	-	11.0
Visiting Faculty	-	4	1.6
Research Associates	3	-	3.0
Graduate Research Assistants	-	-	22.5*
Graduate Teaching Assistants	-	-	1.3*
Administrative and Clerical	7	-	7.0
Other Nonacademic Employees	41	12	47.5
Total	62	16	93.9

* This is an average figure based on the total working time of research and/or teaching assistants for the month.

The Laboratory Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbaum, J. E. Robertson and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

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PART II - CIRCUIT RESEARCH PROGRAM
PART III - DATA REDUCTION METHODS
PART IV - ILLIAC USE AND OPERATION
PART V - IBM 650 USE AND OPERATION
PART VI - GENERAL LABORATORY INFORMATION

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PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Main Arithmetic Unit (MAU) Tests

During the month, the installation of the power supply and cooling systems in the basement was completed, necessary main frame wiring was finished, and tests were begun of the repetitive sections of the MAU.

Transistor counts for the equipment involved are as follows:

9 Repetitive sections of MAU (4 bits each)	5067
Driver-driver and reply circuits	288
Test control	432
9 Power supply regulating modules	585
Total	6372

All chassis were installed on 27 July, with error-free operation first achieved on 29 July. During the initial 12 hours of operation on July 30 and 31, the mean time to failure was approximately 20 minutes, with the longest correct run 1 hour and 7 minutes.

During the installation and initial operation, the following eighteen faulty components were found:

14 open 3-watt wire wound resistors

3 shorted filter condensers

1 faulty stabistor

The test control is the one used for dynamic tests of the individual MAU chassis (see March Progress Report), with inverters and cable drivers added where needed.

The test procedure is an extension of the Fibonacci sequence (modulo 15) previously used on individual sections. End around connections were

made between the most and least significant of the 36 bits in the nine repetitive sections. The same pair of 4 bit numbers is placed in each of the nine sections. As long as no error occurs, the information flow is the same across each boundary between sections, so that each section behaves as if it were individually end around connected. The effect of an error, however, is to change the pattern to a different sequence, modulo 2^{36}-1, and the identity of patterns in individual sections is quickly lost. It is thus unlikely that an error will not be detected.

(C. E. Carter, M. Melman, G. Metze)

2. Physical Aspects of Machine Construction

2.1 Chassis Frames

The second order of chassis frame pairs was for 100 complete frames. Of this number 75 pairs have been delivered to our Laboratory.

(C. E. Carter, T. E. Kerkering)

2.2 Air Conditioning

The compressor and air-handling unit and ducts for the main frame are complete and in operation.

The compressor and air-handling unit for the drum and core is ready for operation but has not been tested. A small length of output duct is waiting for insulation and wrapping.

2.3 Shop Progress

	MAU	Flow-Gating	1/2 Core
Complete Chassis	46	24	47
Without Male Frames	7	14	1
Needs Inspection	2		
In Wiring Stage	3		
Spares	1	2	4

In addition to the regular wiring load the shop has played a major role in the following:

Complete DC distribution of power in the power supply room.

Completion of interconnections for proper operation of 9 power supply regulator modules.

Wiring the final portions of end-around connections and cable driving for operation of 9 bays or 27 chassis of main arithmetic unit.

Fabrication of and installation of a DC monitor for the core unit.

Construction of the two remaining capacitor banks, making the seven power supplies complete.

Fabrication and assembly of top section of frame for 4096 words of core storage and interplay.

(T. E. Kerkering, F. P. Serio and Shop)

3. Drawings and Layout

3.1 Revised Drawings

The revisions started last month on these drawings were completed in July.

1020 - Q6F	1008 - Q7F
1002 - A6F	968 - Q4C
1006 - S6F	1018 - S6R
1028 - Q6R	1016 - A6R

In addition the following drawings were revised.

977 - Q2-3C	- S5C
1076 - A5C	- S3C
976 - A3C	1075 - Q5C

3.2 Block Layout

These circuits were blocked out in preparation for shop work and drafting.

1040 - Q8C	1004 - S7F
1036 - A8C	1010 - S8F
1154 - A6C	1000 - A7F
1201 - Q16RC	

The following block layouts were started.

1034 - Q7C	1170 - Q8F
1030 - A7C	1012 - A8F
1153 - Q6C	

(H. E. Lopeman, S. P. Krabbe)

4. Core Memory

Construction of all chassis for the core memory is now complete. Wiring of the control section of the memory frame is about 50 per cent complete.

Wiring of the core stack to plugs is under way.

(S. Ray, B. Briley)

5. Circuit Design

The problem of simultaneous inputs to an AND-NOT flipflop has been examined. An improved circuit has been tested which demonstrates apparently satisfactory nonoscillatory operation. File No. 391, "An Improved AND-NOT Flipflop Complex," describes more detail of the results.

An improved over-under voltage detection circuit has been designed and tested. File No. 389, "Over-Under Voltage Detector," gives more details.

(K. C. Smith)

The tolerance analysis for the new slow circuits has been completed. See Dwg. D-1131. Work was begun on the logic and special circuits for the paper tape reader and punch.

(L. J. Peek, Jr., M. D. Freedman)

An estimate of the cost of the July 21 version of "Slow Circuits" was prepared. Excluding power supplies, but including regulator modules, the cost was found to be about $7 per PNP transistor. In arriving at this figure,

the 2N1308 NPN's used in bumps were not included in the transistor count, in order that a more direct comparison could be made with systems not using transistor bumps.

(R. L. Cummins)

6. Delayed Control and End Connections

6.1 Layout

The final layout of the EAU, End Connections, gates and selector mechanisms is still in progress. Modifications and corrections in the logic coupled with circuit difficulties (see below) have produced unexpected delays in this area. In addition to the chassis now built and operating--bays 1-5 front and center wall and bays 1-4 rear wall--the following have been released to the shop and draftsmen: Q6F, A6F, S6F, Q7F, Q5R, A5R, S5R, Q6R, Q7R and S7R. Of these the following were modified during July: A6F, S6F, Q7F, Q5R, A5R, S5R, Q6R, Q7R, Q5C, A5C, S5C and Q4C. The modifications were generally of two types. The first and most common was a rearrangement to make room for cable drivers or to reduce lead lengths and thereby avoid their use. The second involved changing the bumps at the output of certain restoring circuits to make it possible to feed other restoring circuits directly.

The immediate goal of the layout group is to complete the layout of all chassis in the Q, A and S levels of the stem of the T and the two center wall stubs 16 CF and 16 CR. As of the end of July the following chassis were partially or completely laid out but not released: A7F, S7F, A8F, S8F, Q16CR, A16CR, S16CR, Q8C, A8C, A6C, A6R, S6R, A7R, A8R and S8R. These chassis will not be released until the layout of the remaining chassis in the stem and center wall stubs has been completed. This will permit a careful check and modification--if necessary--of the many critical interconnections in this area.

(H. Aiso, S. P. Krabbe,
H. Lopeman, J. O. Penhollow,
R. E. Swartwout)

6.2 Logic

In the process of making a final layout for the various gate and selector mechanisms, the logical diagrams were redone so as to include the required cable drivers. In some instances circuit modifications were necessary to accomplish this. The gate and selector logic in the MAU has been designed to provide both fast and slow replies, the difference being on the order of 3 to 4 collector delays. The driver system now employed in the MAU can be used with both the test control and the final control.

(J. O. Penhollow, R. E. Swartwout)

Due to an error discovered by R. Farrell, it was necessary to modify the division predictors so as to always obtain the true sign of the unassimilated partial remainders α_j and σ_j in the ranges

$$-1 \leq \alpha_j < -\frac{23}{24} \quad \text{and} \quad -2 \leq \sigma_j < -\frac{47}{24} .$$

This involved the examination of two extra bits at the S adder output (σ_{-2} and σ_{-2}^*) and one extra bit at the A adder output (α_{-1}) with a net increase of 16 in the number of transistors. This increase was more than cancelled, however, by other modifications suggested by R. Farrell in the borrow propagation and carry-borrow logic. In the former the P memory element was removed entirely and replaced by a 3 input OR. In the latter the CB_2, BR and A^*_{-2} memory elements were removed along with part of the associated logic. Corrections were also made in the addition and division control logic.

(J. O. Penhollow)

6.3 Circuits

The month was devoted to the following circuit work:

(1) Tolerance Analysis of a Restoring NOT Circuit with -X4 Bump

It was found that the negative output levels of a NOT circuit with -X5 were not suitable to the inputs levels of a $\bar{A}^*$ circuit, i.e., the most negative output level was lower than the most negative allowable input to the $\bar{A}^*$ circuit. The trouble was caused by the negative bump -X5.

The circuit called N_3 was obtained by using -X4 bump instead of -X5 in the normal restoring NOT circuit.

All the necessary voltage levels and currents were calculated.

(2) Calculation of Shift Up and Down Voltages of an AND** Circuit.

An AND* circuit was prepared for eliminating the threshold uncertainty caused in the control circuits.

The AND* circuit was accomplished by not using any level-shifting diodes in it, and its voltage reference shifts, $\Delta V = V_{out} - V_{in}$, were never negative. However, the voltage shifts were too large to be compatible with the least negative allowable level of the $\bar{A}^*$ circuit. When the input signals come from cable drivers or nonrestoring circuits, this problem becomes more severe.

To solve the problem, an AND** circuit was derived by leaving out one level-shifting diode from the normal AND circuit. The reference voltage shifts up and down of the A** circuit were calculated. The threshold requirement of the $\bar{A}^*$ Eccles Jordan Combination has been satisfied. (The result will be published in August.)

(3) Voltage Level Checks on each Element in the Control Circuits.

The voltage levels into each element were computed, and bumps were inserted where necessary. The work will be continued in August.

(H. Aiso)

(4) A new 14-volt Zener bleeder (type T) was designed and tested. It performs the AND function at the collector point and can feed one or two cable drivers or collector followers at its output (see Dwg. C-1117). The collectors of one or two switching amplifiers having 1.6 K emitter resistors can be tied to either leg of the bleeder. Its load capacity is roughly equivalent to that of the Z type bleeder shown on Dwg. C-1117.

The T type bleeder has been incorporated in the Eccles Jordan memory element to provide a cable driven reply. The Z type bleeder may also

be used in the Eccles Jordan to provide cable driven outputs. A basic circuit drawing (D1136) showing the Eccles Jordan with these modifications has been prepared.

(J. O. Penhollow)

6.4 Safety Margins and Delay Lines

Now that the layout and logic of the main center wall bays is nearing completion, reasonably accurate timing analyses can be made. About 25 different safety margin checks were made to insure that adequate time was available for the operation of the various instructions. These checks revealed that 6 different delay lines would be needed to insure proper operation. These are: two lines with 50 ns delay, three with 100 ns delay and one with 200 ns delay. These delays are used in the following places: the MsA selector control to allow time for propagation through the carry generator during assimilation, the Addition Loop, Load Q, Store, Normalize and Divide.

One interesting item is that in most cases where a delay of (t) seconds is needed, it can be obtained using a delay line of either (t) or (t/2) seconds depending on its position in the control logic. It appears that this flexibility will be useful in arriving at the ultimate machine speed.

As a check on the validity of these safety margin checks, a timing analysis was done on the MAU test control as used with 36 bits of the MAU and compared with timing measurements. In no case were the calculations and measurements different by more than 10 per cent and in most cases the difference was much less than this. Since the calculations and measurements are so nearly equal, it is assumed that the time estimates used for the analysis were correct.

(R. E. Swartwout)

6.5 Clear Delayed Control

To establish the initial state of Delayed Control a list was made of the proper settings for the various status and sequencing memory elements. The clear Delayed Control signal (cdc) will set all selectors to zero and set the memory elements as required.

(R. E. Swartwout)

7. Advanced Control

During the month the Address Arithmetic Unit (AAU) was finalized, and certain decisions were made on its layout, and the layout was partially completed. The AAU is that portion of Advanced Control which performs address arithmetic and other 13-bit arithmetic, and sends addresses to either core memory (after suitable checking) or back to the Flow Gating Memory. It is highly interconnected, especially at the output of its adder, and, apart from the adder and the shifter, 13-bit numbers are copied, gated, etc., digit by digit in a parallel manner without interaction between neighboring digits. Thus the layout can have, for example, the flipflops for a 13-bit register spread out over a number of chassis, so the register can be long and have a thin cross section. Indeed, this type of layout is essential because the high connectivity requires that corresponding digital positions of a large number of devices be near each other (less than 2 feet of wire separating them). One section, the block checker, which is responsible for determining, for each address, whether its first 5 bits define a busy block flipflop or a free block flipflop, may conveniently be separated and placed on top of the core memories. The remainder of the AAU was assigned to the Q,A,S levels of the cross of the T not assigned to Delayed Control, namely the bottom 3 chassis on each of two bays, front and back for a total of 12 chassis. The layout of registers, selectors, etc., is vertical with 5-bit positions of any device at the Q level of some chassis, and 4 bits each in the A and S chassis immediately below. This layout is nearly completed and involves about 2000 transistors.

(M. Faiman)

The general structure of the flow chart for Advanced Control has been finalized, namely what control points are required, what branchings between control points must exist, what conditional status flipflops are needed, and what conditional operations are done by each control point. Also, the execution of every order has been described in terms of what operations are done by each control point, and the composite conditions involving groups of orders for every conditional operation at every control point, is nearly complete.

(D. B. Gillies, R. R. Shively)

8. Magnetic Drum Memory

Experiments were performed on the magnetic disk using the selection switch, write amplifier and read-out register. A clock track was written at an approximate density of 250 bpi. The output of this track was amplified, squared, and then recorded on a second track. Output from the "information" track was compared with the clock signal. The delay between the clock signal and the time of maximum output of the information track was approximately 0.3 μs which is the amount by which the read strobe should be delayed.

The driver circuit for the row and column select switches and write amplifiers was tolerance analyzed and suitably modified. The head selection matrix has also been analyzed and the circuit finalized

(C. N. Liu, P. V. S. Rao)

In the May, 1961 report, a reading scheme was mentioned briefly which corrects errors caused by spreading of the read pulse into adjacent bit cells. That scheme uses amplitude detection followed by Boolean manipulation, and it produces a delay of one or two bit periods, depending on the complexity of the manipulation. An alternative scheme is a peak detector which utilizes both the amplitude of the read voltage and its derivative. An experimental circuit has been developed, and is now under test. Its delay is only a fraction of a bit period.

The parity circuit is being revised in view of the recent decision that the Drum Buffer will not handle character parity (a 14th bit for every character) but will handle only word parity (a 53rd bit for every word). The drum electronics will still generate and check character parity as before, and it will accumulate the character parities modulo 2 for comparison with, or generation of, the 53rd bit.

A Waiting Time Alarm Circuit was developed. It operates if the Drum Memory fails to transfer a block within one revolution after a request is received by the Drum electronics. This circuit will detect a large class of errors in the Drum Memory. It operates from the origin clock track, and does not contain any analog timing circuits.

A manuscript describing the detailed design of the Sector Selection and Timing Circuits (Drawing D-1300) is being prepared.

(M. Falleni)

The differential read amplifier operates on a nominal 50 millivolt input, yet it must recover quickly from the overloads caused by the large writing and head selection voltages. The performance of the amplifier shown in Fig. 1 was tested using the circuit of Fig. 2. The sine wave oscillator and transformer supply a small differential-mode signal to simulate the read voltage from a drum head; the pulse generator supplies a common-mode signal to simulate the large head selection voltages. The results pictured in Fig. 3 and 4 show that the common-mode signal is effectively eliminated, and that recovery from the overload is substantially complete in 10 μsec.

(H. Yazaki)

9. Magnetic Tape Memory

An estimate of the equipment required to effect the base 8 - base 7 excess 1 conversion (proposed for high-density high-performance tape memory) was prepared for comparison with conventional recording methods. The conversion process was found to require about 2000 transistors more than methods in which the error-correcting code is applied directly.

(R. L. Cummins)

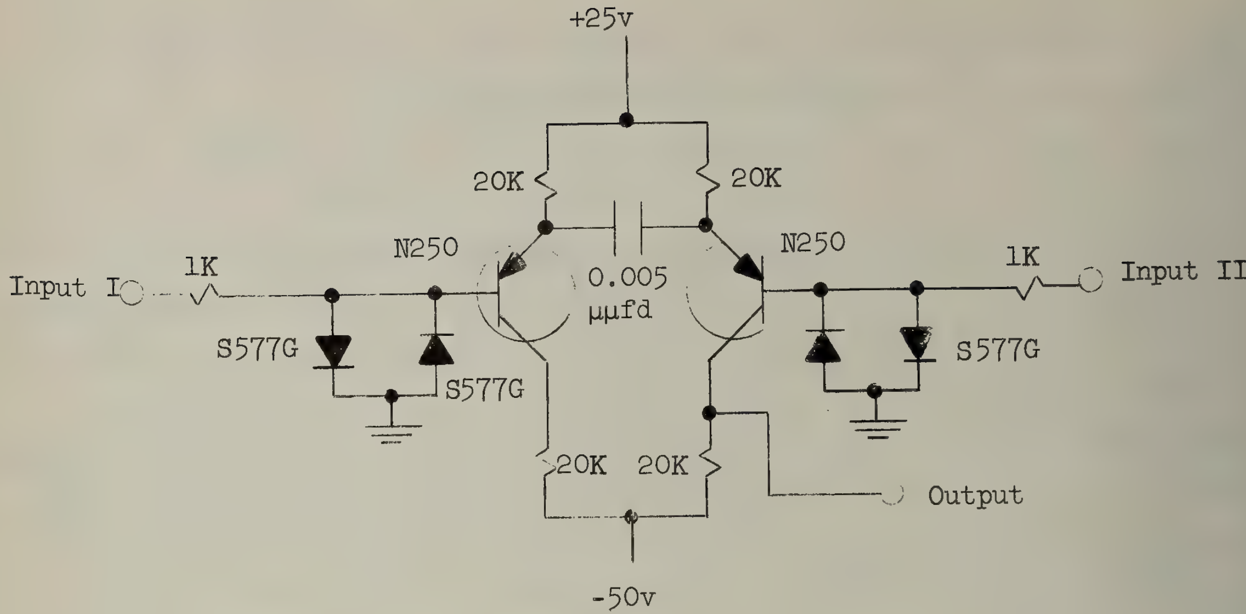


Figure 1

Read Amplifier

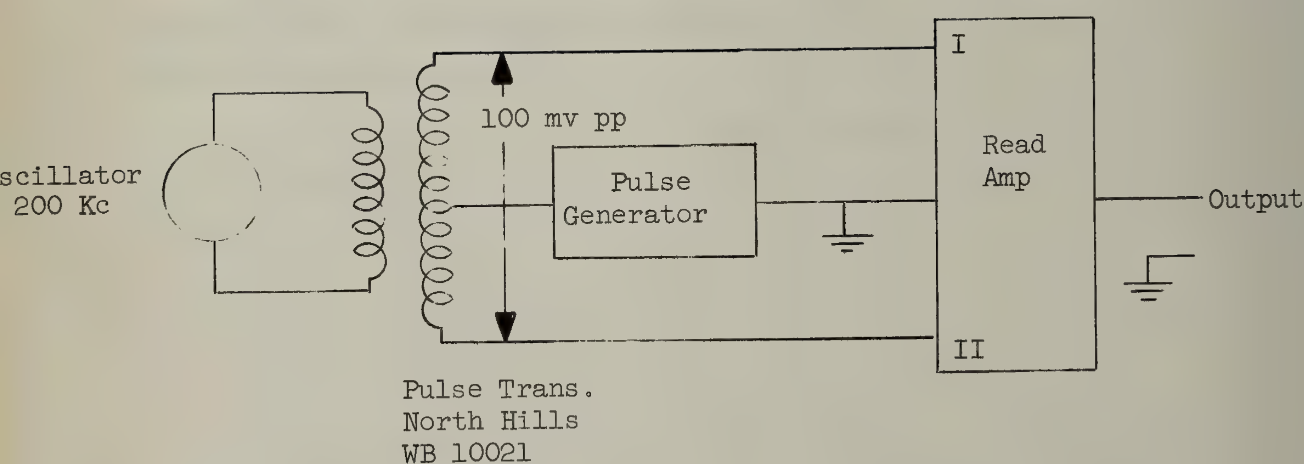
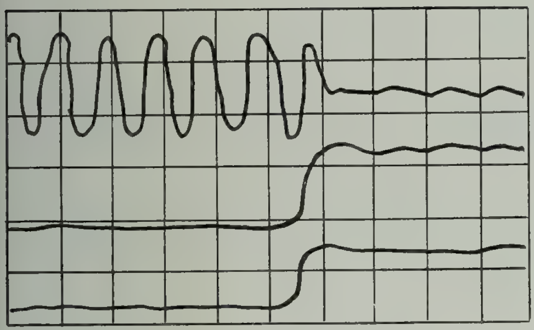


Figure 2

Test Circuit



Read Amplifier output, 10v/div.

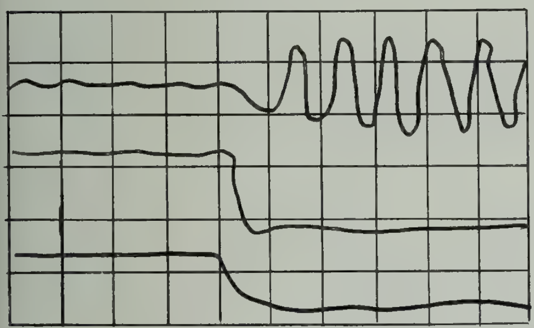
Pulse Input, 2v/div.

Output of Diode Limiter, 0.2v/div.

5 µsec.

Figure 3

Read Amplifier Waveforms at Beginning of Overload



Read Amplifier Output, 10v/div.

Pulse Input, 2v/div.

Output of Diode Limiter, 0.2v/div.

5 µsec.

Figure 4

Read Amplifier Waveforms at End of Overload

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

In July work was quite diversified. H. Guckel studied the behavior of RCA 1N3130 tunnel diodes on the new Rhode and Schwarz 3000 mc bridge in view of their use in the "auto-pump" circuits described in last month's report. Considerable theoretical work was also done in order to obtain a clearer understanding of the directivity problems encountered.

P. Vittal designed some special jigs to allow the measurement of the hybrid parameters of a transistor at microwave frequencies.

S. Ribeiro started an investigation of the deep-saturation behavior of transistors at audio-frequencies; in particular it is desired to obtain practically applicable base-current curves for given base potentials and collector currents.

G. Ujhelyi did some preliminary calculations on the switching times of a simplified flipflop using phase-plane trajectory methods.

C. Afuso essentially completed the low-swing transistor circuit project. In particular he tested a four-bit shifting register and a counter. The results showed that 100 mc was the upper limit for this type of circuitry.

The results obtained by Mr. Ribeiro and G. Ujhelyi will be described in a later report. The other work is reported on in more detail below.

2. Tunnel Diode Work

The study of the switching behavior of RCA tunnel diodes was continued. It was observed that the 500 mv supply showed high impedance to the high frequency components even though the dc-impedance was less than one ohm and extreme care in wiring was used. This resulted in an investigation of resistors and capacitors used in the supply. The components were found to be inductive above 300 mc.

In order to eliminate this difficulty a statically shielded supply was designed and fabricated. This is shown in Fig. 1.

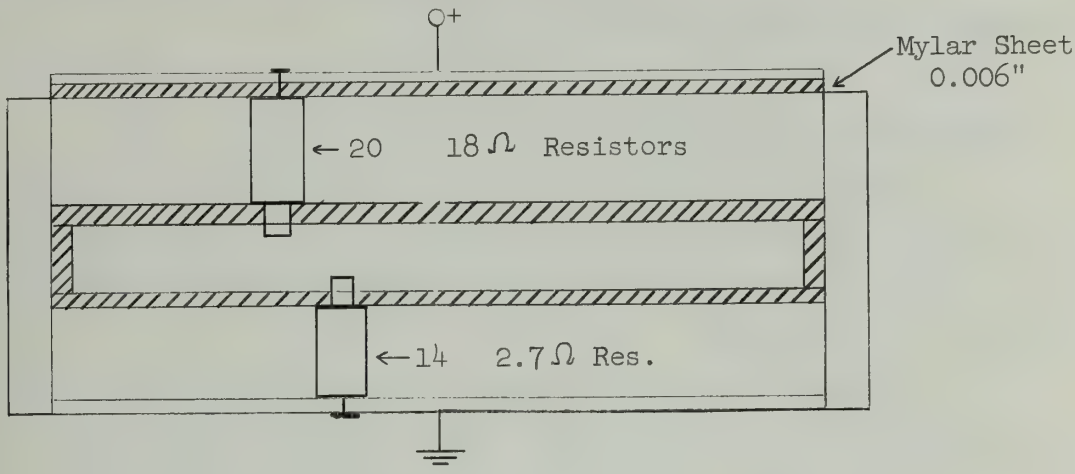


Figure 1

Shielded Power Supply

Three capacitors are provided by the mylar spaced brass shields. The area for each capacitor is about 30 square inches, so that the capacitance is fairly large. In addition each bleeder resistor is imbedded in the grounded brass body. By mounting terminals directly on the divider the interconnecting lead length is eliminated. Evaluation with the diagraph showed good capacitive behavior at frequencies up to 2200 mc.

Some of the tunnel diode circuits were retested using this supply. It was found that the trigger currents are somewhat higher than expected. A graphical analysis was performed on the circuit of Fig. 2.

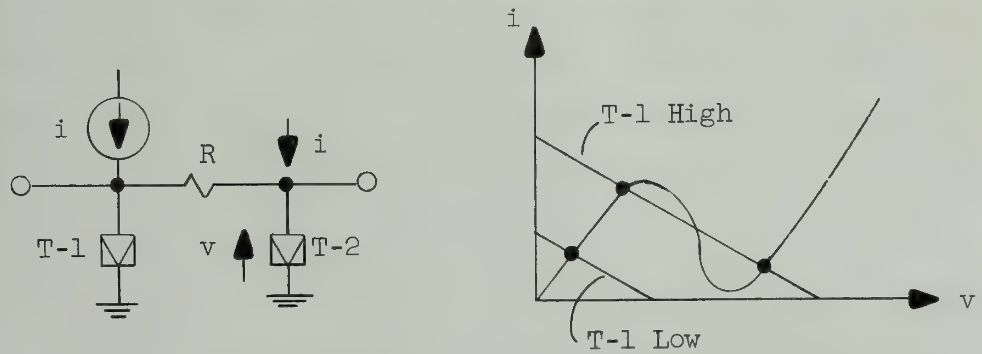


Figure 2

Trigger Test Circuit

The triggering sensitivity is not explainable at the present time. However, the diode T-1 does provide the desired control over T-2. The circuit is being analyzed by a different method.

3. Microwave Transistor Jig

Preliminary work with regard to the study of hybrid parameters of transistors at microwave frequencies was taken up. A suitable jig for mounting the transistor, which can be used in conjunction with the Rhode and Schwarz equipment, was designed.

The Rhode and Schwarz bridge with its oscillator has a 50 Ω coaxial termination at its input and output ends. Therefore, the transistor cannot be directly connected. One of the important design considerations of the jig is the smooth transition from the base of the transistor to the 50 Ω coaxial fittings. Besides there are problems of isolating dc and ac paths. One way to achieve smooth transition from the transistor leads to the 50 Ω coax fitting is to design a tapered coax. For 50 Ω impedance the diameter ratios will be

$$138 \log \frac{d_o}{d_i} = 50$$

$$\text{i.e. } \frac{do}{di} \simeq 2.5.$$

The use of two terminal blocking capacitors and resistors are likely to introduce reflections due to mismatch. Use of coaxial capacitors and resistors would overcome this difficulty. If the impedance of the resistor is about ten times that of the blocking capacitor, the amount of ac flowing into the resistance is negligible and then ordinary two-terminal rf resistors can be used. The tentative design is shown in Fig. 3. The jig consists of two pieces held together by four screws AA as shown. Each piece is made of two identical blocks which are held together by screws. This permits the machining of tapered holes.

4. Low Swing Transistor Circuits

a. Test of 4-Bit Shifting Register

A four-bit shifting register has been built. The test has been done for 5, 10, 20 and 40 mc gating signals. The results were satisfactory. The

block diagram is shown in Fig. 4.

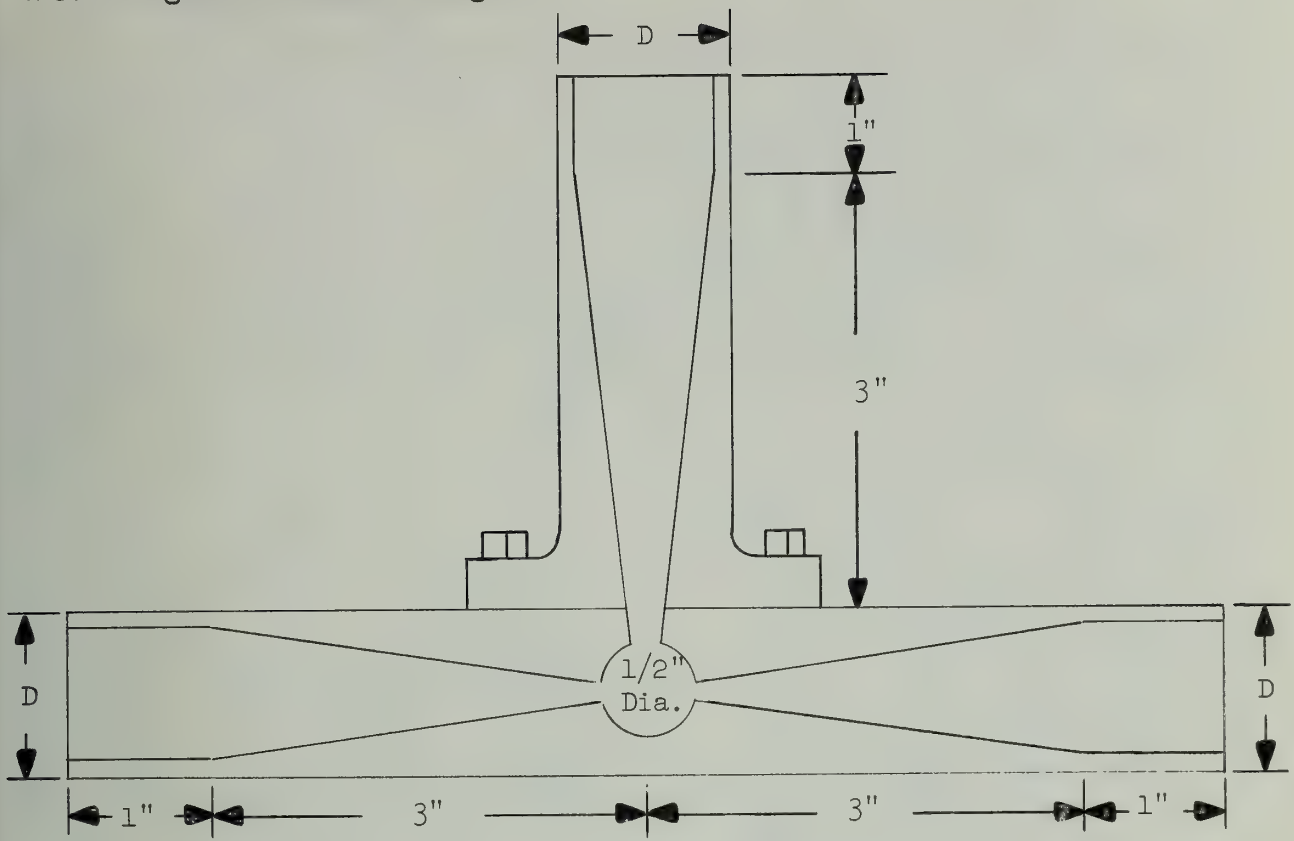


Figure 3

Microwave Transistor Jig

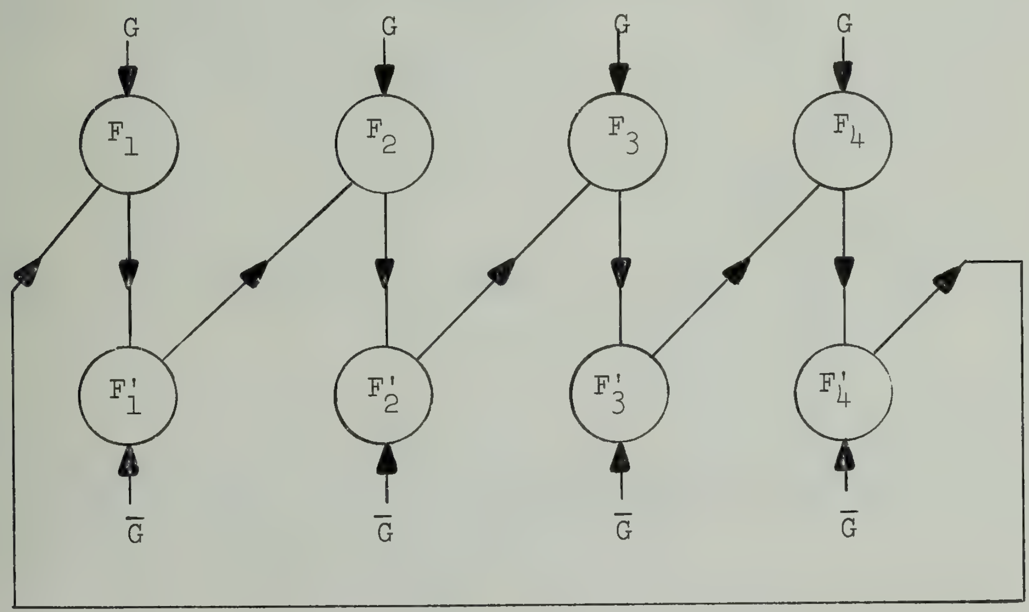
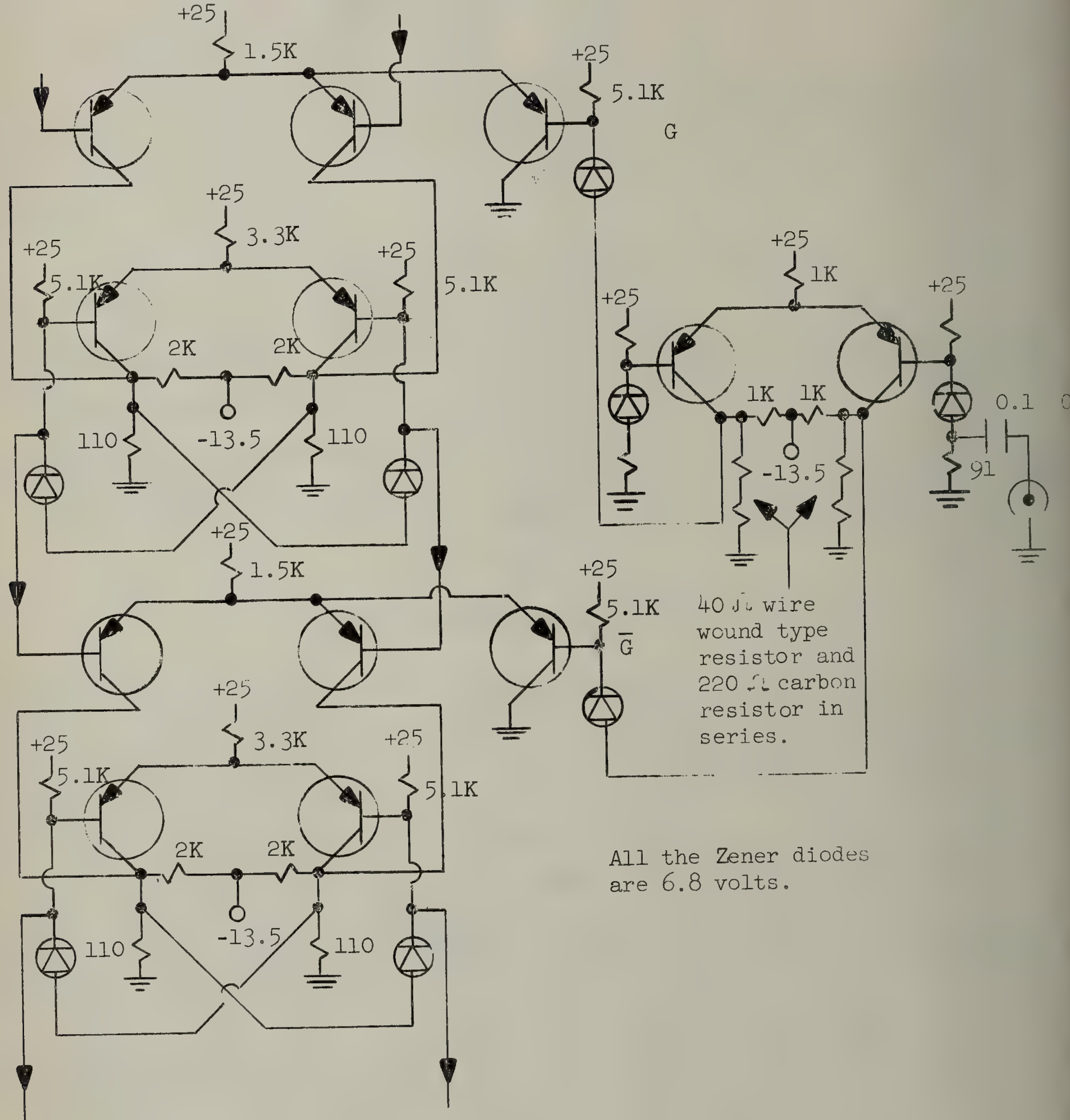


Figure 4

Shift Register Test Setup

The actual circuit for one bit is shown in Fig. 5. The inductance appearing at the collector of the gate driving difference amplifier improves the rise time and the fall time. Without this inductance, the output of the difference amplifier starts to decrease at 40 mc.



All the Zener diodes are 6.8 volts.

b. Counter Circuit

The counter which was reported on last month has been studied in more detail.

As mentioned in last month's progress report, the oscillator must be gated with the signal which we want to count, in such a function that the oscillator oscillates only within a half cycle. In order to assure this, a pulser circuit has been attached in front of the gate. The circuit consists of a difference amplifier and a differentiating circuit as shown in Fig. 6.

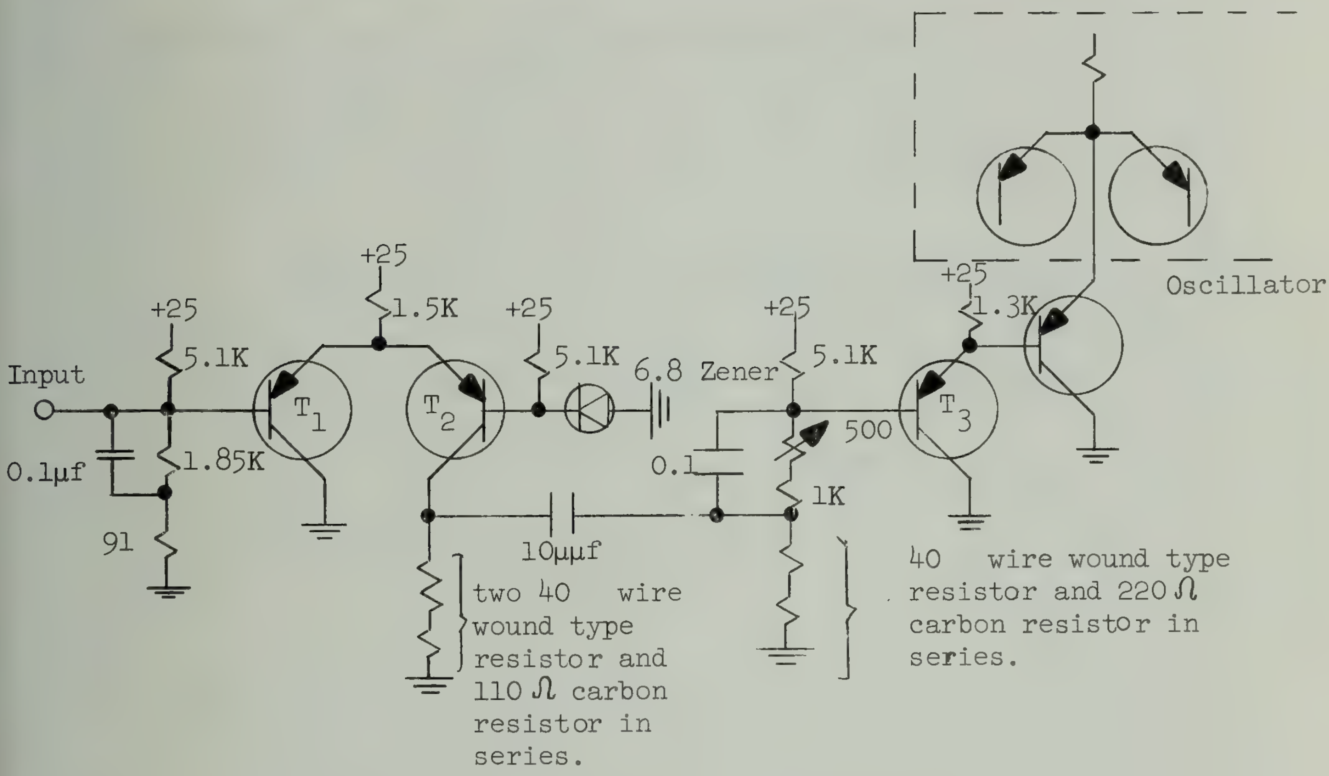


Figure 6
Locking Circuit

The inductance appearing at the collector of T_2 and at the base of T_3 improves the sharpness of the pulse.

PART III

DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

AUTOMATIC REDUCTION OF DATA FROM BUBBLE CHAMBER PHOTOGRAPHS

I. Digital Tracking

The Illiac Tracking Routine has been completely reedited to include the new gap routine and the many changes of the past six months. A first draft of a detailed write up of the routine has been prepared by M. Kuchnir.

II. Minimal Redundancy Encodings using Regular Rectangular Formats

Gray counts (see File No. 377) for 36 rectangular formats have been completed for three plates (plates 4, 5 and 9). Data contractions of 4:1 to 6:1 have been found possible using the above described encoding procedure. The gray counts individually computed for every 32 x 32 domain have been punched out; several near optimum strategies have been computed for each domain. This data is now being examined by standard multivariate analysis, including factor analysis.

Preliminary results seem to indicate that one encoding strategy is satisfactory uniformly over the picture. That is, at present we find no evidence that one rectangular encoding strategies should be used for local areas containing beam tracks and another strategy for electron spirals.

III. Factor Analysis of Pair Count Scores

Detailed mathematical analysis of pair count scoring of both humanly selected and randomly selected domains is essentially complete. Two plates (plates 4 and 5) have been examined both individually and jointly. Analysis includes:

i) correlation matrix with means and variances of all variables

ii) histogram frequency plots of all variables

iii) varimax (orthogonal) factor analysis

iv) oblimax (oblique) factor analysis

IV. Information Theory Applied to Rectangular Encodings

The frequency of all 8, 4 and 2 bit rectangular patterns in typical bubble chamber photographs (plates 4 and 5) are being computed. Either the original digitized photograph or any rectangular projection of it (see File No. 377) is sequentially sampled by the 8, 4 or 2 bit templates. For example, if N rectangular patterns (e.g. 2 x 4 cell divisions) are to be transmitted from the encoding scope to the computer for analysis then by the Shannon Theorem a minimum of NH bits are required to encode this information. Here

$$H = -\sum_{i=1}^{256} p_i \log_2 p_i$$

with p_i = relative frequency of i^{th} (2 x 4) pattern.

(K. Dickman, M. Levitt, B. H. McCormick, J. Stein)

PART IV

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of July, no new routines were added to the Illiac Library.

Illiac Usage

During the month of July, specifications were presented for 23 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2000. Numbers followed by T are for theses.

2000 Aviation Psychology. Monte Carlo Human Tracking Behavior Generator. The purpose of this research is to reduce the description of human tracking performance to a small number of mathematical functions and parameters, and to show that such simplification is legitimate. The evidence of accurate choices of functions and parameters involves the generation of hypothetical tracking data with Monte Carlo techniques using functions and parameters gleaned from empirical data, and then analyzing this hypothetical data to obtain performance measures. If the two sets of performance measures match, then a greatly simplified and accurate description of human tracking behavior is obtained.

2001T Electrical Engineering. Analytical Design of Feedback Control Systems. Library routine J2 will be used to solve for the complex roots of a number of eighth and tenth degree polynomials. These polynomials arise in simulating a practical type of load disturbance and high frequency interference due to feedback transducer noise. To design for an optimum sensitivity function to take care of both these signals, high order polynomials are obtained.

2002 Psychology. Development of a Questionnaire for the Assessment of Parental Attitudes. Parents in 70 families were interviewed and their attitudes toward their children were evaluated. The attitude ratings have been factorized and 8 factors scored for both mothers and fathers. The parents also

answered a questionnaire containing 450 items about child-rearing. The present analysis is needed to develop questionnaire scales for the assessment of parental attitudes by correlating questionnaire responses with the 8 factors evaluated from interview behavior.

The scales will be cross-validated by relating scores on the questionnaire to interview ratings and other variables (25 variables) obtained on a different sample of parents.

2003T Psychology. Fluid and Crystallized General Abilities. The purpose of the study is to isolate some of the general factors involved in performance on intelligence tests and to show how these are related to aging in the range from about 14 to 50 years of age.

Data will be obtained for two samples of persons, a younger group and an older group in two institutional settings, on a set of measures of intelligence. Correlations for each group will be computed. Then a complete factor analysis will be performed. Factor scores will be estimated for each group and these will be compared by multiple regression techniques.

2004 Theoretical and Applied Mechanics. Mapping of the Exterior of a Closed Curve onto the Exterior of a Circle. This problem pertains to the first phase of a research study on the application of complex variable techniques in the analysis of stress problems for solid propellant rocket motors.

Initially it is necessary to determine the function which conformally maps the region exterior to a star shaped curve in the Z-plane onto the exterior of the unit circle in the ζ-plane. If under this transformation, the point $\zeta = e^{i\theta}$ passes to the point z on the boundary of the region in the Z-plane then $\theta(z)$ satisfies an integral equation of the form

$$\theta(z) = \beta(z) + \int_L K(z,s)\, \theta(s)\, ds$$

where β is a known function, L denotes the boundary in the Z-plane, and s denotes arc length. The integral equation must be replaced approximately by a finite system of linear simultaneous equations which are soluble for the values θ_i corresponding to n+1 points z_i of the boundary. These values may then be employed to obtain a function which approximately maps the region $|\zeta| \geq 1$ onto the exterior of the region in the Z-plane. It is known that the

required transformation will have the form

$$Z = \sum_{j=0}^{j=n} Aj \, \zeta^{i-j} \quad .$$

Then it follows that

$$Z_s = \sum_{j=0}^{j=n} Ai \quad e^{i\theta_s(1-j)} \qquad \text{for } s=0,1,\ldots,n.$$

The solution of the above system of simultaneous equations, after separation of real and imaginary parts, determines the coefficients in the mapping function.

2005 Psychology. Structure of the 16PF and ICL. Numerous factor analyses of the Minnesota Multiphasic Personality Inventory have been performed, but none on large samples of diagnosed psychotics. MMPI scores on a sample of 148 males and 160 females, representing the entire psychotic intake of a large state hospital during a period of several months, have been made available. It is desired to see how the factor structures given by these psychotic samples compare with the factor structures obtained consistently from numerous neurotic and normal samples.

2006 Education, Eastern Illinois University. A Study of Verbal Dimensions Related to the Leader Behavior of Teachers. This study is an attempt to ascertain if Shannon's concept of the additive effect of information bits can be applied to establish "reference to authority" as a significant variable in the students' perception of his teachers' leader behavior. Regression analysis shall be used to determine the internal consistency of the postulated verbal dimensions. Oblique factor analysis shall be used to determine the relationships between dimensions.

2007 Agronomy. Dispersion of Fertilizer in Soil. The concentration-distribution curves that are found when a fertilizer is being washed into the soil bear a great resemblance to similar curves which are obtained from miscible displacement experiments in porous media. The equation of the curve is:

$$C(h,F) = \frac{1}{\sqrt{4\pi aF}} \quad e^{-\left[\frac{(h-\alpha F)^2}{4aF}\right]}$$

where $C(h,F)$ is the observed concentration per unit length,

h is the linear coordinate (the depth of soil),

F is the total volume of fluid per unit area that has infiltrated, and in saturated flow,

$1/\alpha$ equals the porosity, and

a is characteristic of the dispersive properties of the porous medium.

The experiments are conducted so that h is a constant, and the concentration of fertilizer, C, in the effluent, F, is measured. Thus what is measured are concentration values, C_i, for given amounts of effluent, F_i, that have passed through a core of soil of depth h. These values will have some errors, and in order to check the theory, the best fitting equation has to be found. This can be achieved by a least squares procedure which minimizes

$$S = \Sigma\,[C(h,F_i) - C_i]^2 \quad .$$

Since the expression for C is nonlinear the values of a and α obtained will represent the best-fitting parameters describing the soil; the mean value of the squares of the errors, S, gives an indication of the applicability of the theory.

2008T Physics. Pressure Dependence of the Heat Transfer Rate Between He^3 and a Solid. In the course of measuring the specific heat of He^3 under pressure, the rate of heat transfer across the interface between the He^3 and the walls of its container also is measured. Using the Fermi liquid theory of He^3 and postulating that the phonons are the heat carriers, Bekarevich and Khulutnikov derive expressions for the heat transfer rate. In order to extract the variation of the heat transfer rate with pressure and compare our results with this theory, we must numerically integrate the rather complicated theoretical expressions. We make algebraic manipulations, using standard library routines to compute arctangents, logarithms, square roots, and to integrate numerically.

2009 Illinois Geological Survey. Serial Correlation. Serial correlations are desired from four groups of cross-bedding orientation obtained from vertical profiles of sandstones in the Illinois Basin. This study is part of a larger project entitled "Sandstones of an Intracratonic Basin". The objective of this project is to document and broaden our understanding of the mechanisms of sand deposition in the basin.

2010T Coordinated Science Laboratory. Averages for Two Sources Having Different Distributions. We consider the problem of two urns, each of which contains balls of different colors with the probability distribution for each urn specified. For urn 1 we designate balls of certain of the colors (or sequences thereof) as being "unacceptable"; and we impose similar designations for the balls of urn 2 (not necessarily the same colors or sequences as those for urn 1). We then commence to pick balls from one of the urns, say urn 1, until an "unacceptable" ball (or sequence of balls) has been withdrawn (the drawing process is to be one involving identical replacement). At this point we commence to pick balls from urn 2 and continue to do so until a so-called unacceptable state has been reached; whereupon, we return to urn 1 and continue this pattern ad infinitum. The problem is to determine what will be the number of balls which are drawn on the average from urn 1, and the corresponding number for balls drawn from urn 2.

2011T Chemistry. Classical Computations on $H+H_2$ Exchange Reaction. The problem consists in developing a reasonable potential energy surface (to conform to quantum-mechanical calculations) for the $H+H_2 \rightarrow H_2+H$ exchange reaction, and ensuing calculation of reaction probabilities, rates and scattering phenomena. The calculations are to parallel those of R. N. Porter who used Illiac to integrate four Hamilton's equations for the case of colinear atoms. For the general case of three dimensions, an additional variable is added. This extends the problem to one involving the simultaneous integration of twelve first order classical (Hamilton's) differential equations of motion.

Since the addition of the third coordinate considerably complicates the problem, it is proposed that the bulk of the computations be carried out on the new machine when it is completed. The Illiac shall be used for developing and mapping the surface and for some preliminary integrations.

2012 Agricultural Economics. Apple Price Trends. Using standard regression routines (K-16, K-14), linear and nonlinear regressions of selected prices on time will be fitted. By appropriate selection of the price series these regressions may be interpreted as seasonal and cyclical price patterns on the relevant markets. Most of the data refer to apple prices on the wholesale markets in Chicago and St. Louis.

2013 Chemistry. Temperature Coefficients of Ionic Activity Coefficients. The thermodynamic description of an electrolyte dissolved in solution is made in terms of its stoichiometric mean molal ionic activity coefficient, $\gamma_{\pm}$. This quantity has been obtained from potentiometric studies and its temperature coefficient is required for the evaluation of two other parameters, the relative mean molal ionic enthalpy, $\bar{L}_2$, defined as

$$\bar{L}_2 = RT^2 \frac{\partial \ln}{\partial T} \gamma_{\pm}$$

and the corresponding heat capacity, J_2, defined as

$$\bar{J}_2 = \frac{\partial \bar{L}_2}{\partial T} \quad .$$

It is necessary to find the best polynomial description of $\gamma_{\pm}$ as a function of T, the absolute temperature, using the criterion of least squares as a measure of fit.

2014 Chemistry. Fourth Order Eigenvalue and Eigenvector. The problem consists in determining the energies and orbital coefficients for a set of molecular orbitals formed from a basic set of four orbitals. We have

$$\Psi = C_1 \psi_1 + C_2 \psi_2 + C_3 \psi_3 + C_4 \psi_4 \ .$$

The energy of the orbital is minimized with respect to the coefficients leading to the following set of equations:

$$\begin{array}{lllll}
2C_1(\alpha_1 - E) & & + C_3\beta & + C_4\beta & = 0 \\
 & 2C_2(\alpha_2 - E) & + C_3\beta & + C_4\beta & = 0 \\
C_1\beta + C_2\beta & & + 2C_3(\alpha_3 - E) & & = 0 \\
C_1\beta + C_2\beta & & & + C_4(\alpha_4 - E) & = 0
\end{array}$$

In matrix notation this amounts to finding the eigenvalues, E, and vectors for

$$|C - EI| \; U = 0 \quad .$$

Given several sets of values for the α's and β's, Illiac will be used to solve for the eigenvectors and eigenvalues.

2015 Psychology. Chicago Street Gang Study. Four hundred and fifty youths from street gangs in the Chicago area have been rated on forty-seven tests from the O-A Personality Factor Battery. These data will be factor analyzed and the resulting factor matrix will be rotated to oblique simple structure in order to determine whether, or to what extent, the structure previously found characterizes this new sample.

2016T Electrical Engineering. On Increasing the Effective Aperture of Antenna Systems. The problem entails the solving of a set of N linear simultaneous equations which arise from a curve fitting by the least squares technique. The coefficient matrix is a positive-definite Toeplitz form, but becomes ill-conditioned as its size increases. Consequently direct inversion of the matrix is not possible. A method of iteration involving a modification of the matrix will be attempted. Various matrix sizes will be tried and the largest possible will be used (i.e., N might approach 100). The method of iteration is the one proposed by Professor Li Chao and Professor Edward Scott of the Department of Mathematics.

2017 Aeronautical and Astronautical Engineering. The Structure of Strong Shock Waves. Shock wave calculations have been made by students and staff of the Aeronautical and Astronautical Engineering Department.

The Boltzmann equation for a steady state shock wave may be written as

$$v_x \frac{\partial f}{\partial x} = a - b\, f$$

where

$f = f\,(\bar{v}, x)$ is the molecular velocity distribution function,

and

$(a - b\, f)$ is the collision integral.

The functions a and b are evaluated, by a Monte Carlo method due to Nordsieck, for $f = f^{(o)}$, the zero-th approximation to f. The Boltzmann equation is then integrated for each velocity bin to give $f^{(1)}$, the next approximation to f. Iteration of this procedure is carried as far as is appropriate in view of the fluctuations in the a, b caused by the MC evaluation. These fluctuations are reduced within each iteration by smoothing in velocity space.

Calculations will be made for a range of shock strengths. Various characteristics of the numerical method will also be studied.

2018 Aeronautical and Astronautical Engineering. Plotting of Isolines. Under Problem Number 1659 a method for plotting isolines on the Illiac cathode ray tube was programmed.

Additional machine time is requested to make revisions and to prepare the program for the library. Several small research problems will be used to check the routine.

2019 Institute for Research on Exceptional Children. Special Class Project Study of Mentally Retarded Children. Fifty mentally retarded school children in special classes and fifty in regular grades were measured on twenty-four tests of intelligence and achievement.

Correlations for each group were obtained on the IBM 650 (Problem Number 274'). It is now desired to do further analysis on Illiac. Several regression coefficients for each group will be computed using K-16.

2020T Psychology. Effects of Infantile Experience on Adult Behavior in White Rats. This study is to assess the effects of infant handling and shock procedures upon the later development and behavior of white rats.

Illiac will be used to perform an analysis of variance and covariance on the adult measures to determine the relative efficacy of the infant treatments. In addition correlations of treatment by measures and individuals by measures for further information about the similarities among the measures will be obtained.

2021T Mechanical Engineering. Drag in Separated Flow Regions. In this study the transformation of the boundary layer momentum thickness through a Prandtl-Meyer expansion is solved by a trial and error method using floating point arithmetic. The results will be related to the initial and final Mach numbers and the constant for the power law boundary layer profile.

2022 Psychology. Data Source Effect on Parent-Child Evaluation. This is a study of the effect of data source on the information gained in evaluating parent and child behavior. The analysis involves a comparison of factors (previously obtained) on parents and children from three sources: interviews with parents, direct observation of parents and children, and self ratings by parents.

Illiac will be used to compute correlations among the various sets of factor scores. This matrix which will contain variance from the three sources will then be factor analyzed.

Table I shows the distribution of Illiac machine time for the month of July.

TABLE I

	Hrs:Min	
Scheduled Engineering	59:21	
Unscheduled Engineering	22:37	
Drum Test	4:45	
Leapfrog	3:20	
R.A.R.	:20	
DCL Library Development	6:33	
Classes	31:50	
Instruction	:01	
Demonstration	2:14	
		131:01

Use by Departments

Administration	:09
Aeronautical Engineering	:06
Agricultural Economics	17:10
Agronomy (0015-15-306)	2:57
Agronomy	7:36
Animal Science	5:01
Astronomy (NSF G-14834)	5:48
Bur. of Community Planning (84 16 383)	:30
Bureau of Economic and Business Research	6:16
Chemistry (NSF G-5907)	5:17
Chemistry	78:49
Civil Engineering (NSF G-6572)	3:08
Civil Engineering (AASHO ROAD TEST)	10:42
Civil Engineering	112:06
College of Medicine	2:54
Coordinated Science Lab. (DA-36-039-SC56695)	62:30
Digital Computer Laboratory (Nonr 1834(27))	1:37
Digital Computer Lab. (AEC AT(11-1)-415)	2:16
Digital Computer Laboratory (US TR AEC-1018)	14:17
Economics (NSF G-7056)	3:59
Education	3:14

(cont'd.)

Use by Departments
(cont'd.)

	Hrs:Min		
Electrical Engineering (Nonr 1834(22))	3:55		
Electrical Engineering (AF 33(616) 6079)	:07		
Electrical Engineering (NASA-NSG 24-59)	5:58		
Electrical Engineering (NOBSR 64723)	3:50		
Electrical Engineering (AF 7043)	3:56		
Electrical Engineering (AF 4622-25-314)	:54		
Electrical Engineering (SL 85173)	:07		
Electrical Engineering	2:28		
Food Technology (50-343)	:27		
Geological Survey	2:04		
Inst. of Communications Research (44-28-20-378)	12:14		
Inst. of Com. Res. (USPHM-3941 46-28-20-364)	6:25		
Institute of Communications Research	4:23		
Inst. of Labor and Indus. Rela. (00 6010 300)	1:43		
Marketing	:28		
Mathematics	8:51		
Mechanical Engineering (DA-11-022-ORD 1980)	:09		
Mechanical Engineering	4:32		
Mining and Metallurgical Eng. (TRUS AF6770)	:12		
Mining and Metallurgical Engineering (CML 51F)	3:09		
Mining and Metallurgical Engineering (AF420)	1:01		
Mining and Metallurgical Engineering	2:29		
Music	1:36		
Natural History Survey	:06		
Office of Instructional Television	1:52		
Petroleum Engineering	4:32		
Physical Education	:08		
Physics (AF 49(638)-529)	1:25		
Physics (Nonr 1834(05)A)	18:27		
Physics (A. P. SLOAN-SLICHTER)	:01		
Physics	39:08		
Psychology (MD 2060)	3:14		
Psychology (AF 49(638)371)	2:12		
Psychology (1715)	:40		
Psychology (AF 41(657)279)	:39		
Psychology	75:40		
Sociology	:10		
State Water Survey (DA-36-039-SC75055)	3:47		
State Water Survey	5:09		
Theor. and Applied Mech. (NOBS 72069)	:08		
Theor. and Applied Mech. (DA-11-070-508 ORD)	13:08		
Theoretical and Applied Mechanics	2:45		
		590:31	
			721:32

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance, and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Memory	3
Arithmetic	3
Reader	3
Punch	4
Drum	9
Power Supplies (one caused by storm)	2
Unknown	2
TOTAL	26

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/1/61	24:00	:00	:00	0		:00	:00	0
7/2/61	24:00	:00	:00	0		:00	:00	0
7/3/61	21:08	:15	2:37	2	(1) Punch failure. (2) Unknown	:00	:25	0
7/5/61	14:38	6:12	3:10	2	(1) Broken +100v buss, arithmetic unit (2) Punch failure	:00	:00	0
7/6/61	19:49	:42	3:29	2	(1) Low filament voltage caused failure. (2) Memory pos. 2^{-30} failing, cause not determined.	:00	:00	0
7/7/61	21:10	:20	2:30	1	(1) Drum failure	:00	:03	0
7/8/61	24:00	:00	:00	0		:00	:00	0
7/9/61	24:00	:00	:00	0		:00	:05	0
7/10/61	21:33	:00	2:27	0		:00	:08	0
7/11/61	21:41	:00	2:19	0		:00	:00	0
7/12/61	20:18	:00	3:42	0		:00	:09	0
7/13/61	20:14	:07	3:39	1	(1) Reader "F" failed	:00	:25	0
7/14/61	20:16	1:14	2:30	2	(1-2) Drum failures	:00	:07	0
7/15/61	22:31	1:29	:00	2	(1) Drum failure.. (2) Punch failure	:00	:00	0
7/16/61	21:53	:00	2:07	0		:00	:00	0
7/17/61	21:10	:00	2:50	0		:00	:07	0
7/18/61	20:42	:00	3:18	0		:00	:00	0
7/19/61	20:04	:27	3:29	2	(1) Unknown. (2) Drum failure	:00	:00	0
7/20/61	17:27	4:03	2:30	4	(1-4) Drum failures	:00	:00	0
7/21/61	17:15	4:15	2:30	2	(1) Reader "I" failure. (2) Line voltage drop, caused by storm.	:00	:00	0
					(cont'd.)			

TABLE III (cont'd.)

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/22/61	24:00	:00	:00	0		:00	:00	0
7/23/61	23:50	:10	:00	1	(1) Punch failure	:00	:00	0
7/24/61	20:30	:03	3:27	1	(1) Reader "H" failure	:00	:21	0
7/25/61	21:13	:00	2:47	0		:00	:00	0
7/26/61	17:39	2:50	3:31	3	(1) Arithmetic failure (2) Memory failure 2^{-9} (3) Memory failure 2^{-9}	:00	:35	0
7/27/61	19:29	1:09	3:22	1	(1) Arithmetic failure	:00	:00	0
7/28/61	21:08	:00	2:52	0		:00	:00	0
7/29/61	24:00	:00	:00	0		:00	:16	0
7/30/61	24:00	:00	:00	0		:00	:00	0
7/31/61	21:38	:00	2:22	0		:00	:00	0
TOTALS	635:16	23:16	61:28	26		:00	2:41	0

PART V

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New International Business Machines 650 Codes

During the month of July, one new 650 routine was added to the International Business Machines 650 Library.

L2' - 73' <u>Simultaneous Linear Equations Solver (Without Inversion of Associated Matrix)</u>. The program will solve a set of simultaneous linear equations with an associated matrix n by (n + m), where n is the number of equations and m is the number of sets of solutions (or the number of right hand side constants). The calculation is made with floating point numbers and the output elements are in floating point form. The standard elimination method is used.

(Mary Gray)

International Business Machines 650 Usage

During the month of July, specifications were presented for 16 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 284'T. Numbers followed by T are for theses.

284'T Structural Research. Slabs with Cantilevered Edges. The problem is to determine the effects of different widths of cantilevered edges, beam rigidities, and column stiffnesses, on the intensity and distribution of bending moments in a slab. The computer will be used to solve the matrices obtained by application of finite difference equations.

285'T Education. The Affective and Cognitive Merit of University Education Students. An inventory of three hundred items has been constructed. Two scales have been included in this: (1) a scale measuring the teacher's ability

to promote good teacher-pupil relationships, and (2) a scale measuring the teacher's ability to promote understanding of the subject matter.

One of the purposes of the study is to take a first step in lengthening the second scale, by finding items correlated with the total score in that scale and uncorrelated with the score in the first scale.

A second purpose is to obtain additional information about what each scale measures, by studying the correlations of the scales with opinions on educational matters.

286'T Psychology. Overt Response in Teaching Machine Programming. This research is aimed at determining whether a learner, using a standard teaching machine program, learns more efficiently when he responds overtly or covertly. Pilot data indicate that on the average there is no difference in subsequent retention measures between groups using overt (writing the answer out) responses and covert ("thinking" the answer) responses. However, the pilot data suggest that the overt response technique may have a different effect on correlations between retention measures than does the covert technique, and it then becomes advisable to determine as many of the correlations among these variables as is practical. The IBM 650 will be used to intercorrelate all sixteen variables. Also, an analysis of variance on some of these variables will be calculated.

287'T Dairy Science. The Additive, Dominance, and Epistatic Effects of Six Mutant Loci on Some Quantative Characters in Drosphila Melanogaster. This problem involves adjustment of data for environmental effects prior to subdividing the genetic variator associated with mutant loci in Drosophila Melanogaster. The IBM 650 will be used for the solution of four sets of least squares equations by calculating the inverse of the reduced independent variable matrix. Two of the matrices are of size 21 x 21 and the other two are of size 17 x 17.

288'T Sociology. Change in Inmate Perception. The purpose of this problem is to attempt to ascertain if changes in the perception of prison inmates regarding themselves, other inmates, prison staff, and other non-criminals occur during the incarceration period. Scores are obtained which ostensibly represent

the degree of favorability with which an inmate views himself or others. For purposes of analysis it will be necessary to obtain the mean perception score for 10 concepts for 8 groups of inmates classified according to the proportion of their sentence that they have served. A further classification on a variety of background variables will be obtained. Then tests of significance of differences between the mean perception scores of the various groups will be calculated.

289'T Theoretical and Applied Mechanics. Creep of Curved Beams. In a study of the creep of curved beams it is necessary to find a solution for a complicated and lengthy nonlinear equation in one unknown. The IBM 650 will be used to find a solution using a trial and error approach.

290'T Animal Science. Study of the Effect of Ewe Wintering Variables on Gain in Carcass Weight. This problem is to determine how the previous treatment of ewe wintering ration, creep of the lamb, sex, and hormone treatment of the lamb affect the loin eye area, specific gravity, and average daily gain based on the chilled carcass weight and other measurements. The IBM 650 will be used to perform several regression analyses.

291' Home Economics. Correlations Among Child Rearing Variables. The IBM 650 will be used to compute a correlation matrix. The variables are from derived scores of two parent attitude surveys concerning child rearing. These are Shoben's University of Southern California Parent Attitude Survey and his Parent Attitude Research Instrument.

292'T Dairy Science. Effects of Changes in Body Weight on Milk Production. Measurements were obtained for purebred and crossbred cattle on body weight during lactation and on milk production and percent of butter fat. Regression analysis on changes in weight will be computed using the inverse matrix method. There will be ten inversions of size 10 x 10.

293' Food Technology. Corn Quality Study. In order to study the quality of canned whole kernel corn, a set of physical measurements on the raw product and other measurements from chemical analyses were obtained for a number of samples. A correlation matrix for these variables will be computed.

294' Coordinated Science Laboratory. Practice Problems for IBM 650. For the purpose of becoming familiar with the IBM 650, a number of programs will be written and tested with small amounts of data. These programs will be of the following types: generating random numbers, sorting procedures, evaluating a polynomial, solving nonlinear second order differential equations, and evaluating an elliptical integral.

295'T Physical Education. Performance of Delaware Students. A number of measurements were obtained on a sample of public school students of the State of Delaware. These measurements include age, class, and physical performance tests such as pull-ups, set-ups, standing broad jump, fifty yard dash, six hundred yard run, and distance of a soft ball throw. The computer will be used to obtain measures of central tendency and measures of the variability for these students.

296'T Education. A Study of Two Instructional Methods for Mentally Retarded Adolescents. Forty mentally retarded adolescents were tested to study the effectiveness of two instructional methods on teaching machines. A number of personal characteristic measurements, such as I.Q., age, sex, etc., were taken on each subject as well as pre-test and post-test measurements for the purpose of evaluating the teaching methods.

These adolescents will be divided into several groups. Product moment correlations, means, variances, etc., will be computed for each sample group in order to evaluate the group performances.

297' Education. Study of Communication Structure. This is a study of the impact of directed change upon some organizational variables of a public school. Communication structure is a key variable. The IBM 650 will be used to complete a matrix analysis of communication structure. Three 30 x 30 matrices are to be squared and cubed.

298' Civil Engineering. Study of Traffic Engineering Functions. This study is designed to correlate the activity level of performance for various traffic engineering functions with city size. This will involve the computation of eighteen simple linear regressions with the necessary correlation

measures for a sample size of approximately sixty. Regression lines are to be established for each measure of activity level as a function of population. Statistics to be calculated include: means, standard deviations, regression coefficients, correlation coefficients, standard errors of estimate, and standard errors of regression coefficients.

299'T Physical Education. Prediction of 600 Yard Run Times. An analysis of approximately 30 variables will be made in an attempt to explain the variance in the 600 yard run in terms of oxygen intake, oxygen debt measures as well as neuromuscular tests such as strength, speed, reaction time and power. The variables will be intercorrelated, and in addition a set of multiple regression coefficients will be calculated.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of July.

TABLE I'

		Hrs:Min	
Scheduled Engineering		19:19	
Unscheduled Engineering		30:40	
Air Conditioning		:11	
Tape Test		1:18	
Library Development		32:48	
Agronomy Library	1:45		
DCL Library	30:05		
SSU Library	:58		
Classes		4:03	
CE 391	4:03		
Instruction		:14	
Demonstration		1:10	
Wasted		3:03	
			92:46

Use by Departments

Animal Science	:10
Astronomy	5:59
Chemistry	14:41
Civil Engineering	3:25
Coordinated Science Laboratory	:04
Dairy Science	1:00
Electrical Engineering	9:58

(cont'd.)

Use by Departments
(cont'd.)

		Hrs:Min		
Food Technology		:03		
Graduate College		2:41		
Institute for Research on Exceptional Children		:56		
Marketing		1:19		
Mechanical Engineering		18:22		
Mining and Metallurgical Engineering		15:53		
Physical Education		:57		
Physics		:15		
Psychology		:49		
Small Homes Council		2:38		
State Water Survey		15:09		
Statistical Service Unit		133:03		
Agricultural Economics	4:03			
Agricultural Extension	:38			
Bureau of Community Planning	4:08			
Bureau of Institutional Research	1:14			
Bursar's Office	7:17			
Business Office	16:04			
Civil Engineering	:59			
Dairy Science	8:11			
DHIA	33:58			
Education	9:23			
Finance	2:58			
Marketing	9:24			
Navy Pier	:49			
Physical Education	:15			
Psychology	:09			
Sociology	20:46			
Statistical Service Unit	:08			
Student Counseling Service	12:39			
Theoretical and Applied Mechanics		2:33		
			229:55	
				322:41

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for July.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

407 accounting machine		5
Cycles when shouldn't	1	
Prints incorrectly	1	
Spaces incorrectly	2	
Reads incorrectly	1	
533 card read punch		2
Card jam	1	
Reads incorrectly	1	
650 console and magnetic drum unit		8
Missing bits in register	7	
False storage selection	1	
652 and 727 tape control and tape units		5
Tape unit rewinds incorrectly	2	
Tape unit load rewind incorrectly	1	
Tape is read incorrectly	2	
653 high-speed storage, floating point, and index register		8
False storage unit lights	7	
Index registers and core not working correctly	1	
Air Conditioning		2
Total		30

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
7/3/61	12:26	3:30		:09	1		Tape unit 3 did not do a rewind properly.
7/5/61	14:25		1:20	:29	3		(1)Tape unit 1 would not load rewind. Finally did. (2) False storage unit lights. Tubes changed in 653 and trouble disappeared. (3) Distributor lost quinary bits in position 9.
7/6/61	13:51		2:00	:11	3		(1) 407 not spacing properly. Bad circuit found in board. (2) False storage selection lights. (3) False storage unit lights
7/7/61	15:48		:05	:16	1		Card jam in 533 read.
7/10/61	10:29	3:54	1:50		2		(1) 407 inputs incorrectly. Dirty circuit breaker. (2) 407 not printing in word one. Two broken wires found.
7/11/61	16:18			:10	0		
7/12/61	16:16			:12	0		
7/13/61	16:15			:24	0		
7/14/61	16:13			:07	2		(1) False storage unit lights. (2) Card column 75 did not read from 533.
7/17/61	12:03	3:59			2		(1) False storage unit light. (2) Lost quinary bit in position 5 of the distributor.
7/18/61	15:50			:11	4	:11	(1) False storage unit light (2-3) Air conditioning kicked out. (4) 407 would not space on-line. Finally alright.
7/19/61	15:51		:02	:11	2		(1) Lost quinary bit in pos. 1 of the program register. (2) Lost quinary bit in pos. 3 of accumulator.
7/20/61	15:53			:15	1		Lost quinary bit in pos. 5 of distributor.

(cont'd.)

TABLE III' (cont'd.)

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
7/21/61	15:42			:06	1		Five false storage unit lights. Bad tubes found on 7/24.
7/24/61	12:29	4:08			1		Tape errors in reading tape.
7/25/61	3:03		11:20	:03	2		(1) Tape errors in reading. Plus signs are missing. (2) Indexing and core not working properly. Bad tube found in 653 which was causing both errors. Found on 7/26.
7/26/61	3:42		12:28		0		
7/27/61	14:09		1:35	:11	3		(1) Tape unit 2 did not properly rewind. (2) 407 keeps cycling. Two bad relays found. (3) False storage unit lights due to low voltage.
7/28/61	15:57			:05	0		
7/31/61	12:48	3:48		:03	2		(1-2) Lost quinary bit in position 9 of distributor.
TOTALS	269:28	19:19	30:40	3:03	30	:11	

PART VI

GENERAL LABORATORY INFORMATION

Reports

Report No. 110, "The State Variable Assignment Problem for Asynchronous Sequential Switching Circuits", by C. N. Liu, July 10, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	11	0	11.0
Visiting Faculty	3	1	3.5
Research Associates	3	0	3.0
Graduate Research Assistants	19	7	22.75
Graduate Teaching Assistants	0	2	1.0
Administrative and Clerical	6	0	6.0
Other Nonacademic Personnel	44	9	48.5
Total	86	19	95.75

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors. H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbaum, J. E. Robertson and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - CIRCUIT RESEARCH PROGRAM
PART III - DATA REDUCTION METHODS
PART IV - MATHEMATICAL RESEARCH USING COMPUTERS
PART V - ILLIAC USE AND OPERATION
PART VI - IBM 650 USE AND OPERATION
PART VII - GENERAL LABORATORY INFORMATION

August, 1961

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1) 415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Tests of Repetitive Sections of the Main Arithmetic Unit (MAU)

The first two weeks of August were devoted primarily to debugging the power supply system (see Section 2); the third week to daytime operation of the MAU. Unattended overnight operation was begun on August 24 after the following precautions were taken:

(a) Fusing of each D.C. supply wire for each regulating module at the capacitor banks in the basement.

(b) Dropout circuits to remove power from the MAU if either the MAU temperature exceeds 40° C or the cooling system blower is off.

During the week, August 25 - September 1, the mean time to failure was 14.5 hours, with the longest error-free run being 46.3 hours.

2. Power Supply

2.1 Externally Manufactured Items

Five main (magnetic-amplifier) power supplies and nine regulator modules were put into operation.

The main supplies have only shown one problem thus far, this being leaky tantalum-foil capacitors in the control amplifiers.

The regulator modules have shown several difficulties to date. First, sawtooth oscillations at 2 kc/s repetition frequency were observed when the units were first loaded. The amplitude of this oscillation was as large as 0.5 v peak-to-peak initially. The manufacturer's representative solved this problem by altering the feedback network in all +6.8 amplifiers.

Secondly, the over/under voltage indicating circuit was, in some cases, too sensitive and was incapable of adjustment to lower sensitivity. This was solved by changing one resistor in the over/under voltage circuit.

Thirdly, the etched wiring of the various amplifiers is of low quality. The registration of circuit board contacts with the plug has been particularly annoying.

Nevertheless, none of these problems is difficult to solve.

2.2 Internally Constructed Items

After observing some dependence between the several regulator modules, the grounding system was studied in more detail. It was determined that certain improvements could be made in the ground system. This improvement consisted of minimizing the resistance through which the various main power supply currents flow commonly. On the basis of noise measurements made with the present load, it appears that the ground system, as modified, will be adequate at full load.

The power supply monitor system also showed some defects as follows:

(1) The method of turn-on had to be modified. This trouble was traced to a misunderstanding of the precise details of the over/under voltage signals generated in the power supply regulating modules.

(2) It was found that the power system frequently failed to turn on properly. A rather lengthy investigation revealed that the inductive surge accompanying turn-on of the "high" voltages was being superimposed on the "low" voltage over/under signals. This coupling is, furthermore, by way of the grounding system (see above). This problem was solved by slowing the response of the monitor circuits to a negligible degree.

(S. R. Ray)

3. Physical Aspects of Machine Construction

3.1 Chassis Frames

All orders for chassis frames are complete. The number of frames available in the Laboratory are:

32 (12 x 24)	116 (12 x 18)	6 (12 x 12)
14 (8 x 18)	36 (8 x 12)	

3.2 Air Conditioning

The air conditioning for the main frame, core and drum is complete and checked out. There remain the control adjustments necessary for changes of loading.

3.3 Shop Progress

	MAU	Flow-Gating	1/2 Core
Complete chassis	50	37	47
Without male frames	7		1
Inspection	2		
Engineering changes	13	1	8

In addition to the wiring load the shop played a major role in the following:

An extended ground system for the power supply room.

A co-ax connector panel for main frame and core.

A +65v regulator for the core.

Core stack terminating resistors assembly.

Much general core interconnecting wiring.

Fuses and fuse holder assemblies on the capacitor banks of the power supplies.

Three experimental chassis for reader-punch test.

4. Drawings and Layout

4.1 Block Layout (Delayed Control)

These block layouts were completed with the exception of power requirements.

Q6C-1152	Q16FC-1210
S6C-1156	A16FC-1208
Q7C-1158	S16FC-1206
A7C-1160	S16RC-1200
S7C-1162	A16RC-1201

S8C-1168	A4C -973
Q8F-1170	Q8R -1176
A8F-1012	
S8F-1174	

In addition much time was spent on checking the interconnections for this section of the main frame.

(R. F. Kingsley, S. P. Krabbe, H. E. Lopeman, J. O. Penhollow

4.2 Block Layout (Reader, Punch)

The initial input-output was completed in block form and consisted of the drawings (1401) (1402) (1403) (1404).

(C. E. Carter, L. J. Peek)

5. Circuit Design

To facilitate the detection of shorted conditions occurring in paralleled power transistors within the regulating power modules, a tester has been designed and built. This device is described in File No. 390, "Detection of Paralleled Power Transistor Shorts."

Conversations and correspondence with Mr. E. E. Freeman, President of Chicago Miniature Lamp Works, indicate that a suitable non-linear element can be made to replace the linear resistances presently used to ensure equal current splitting in paralleled power transistors. Elements with a non-linear E-I characteristic will likely provide a more even division of current in the power transistors as well as an indication by intensity of their dull glow, of incipient failures. Mr. Freeman has agreed to produce samples which may indicate the feasibility of this scheme.

Detailed work was begun on the evaluation of delay lines for delayed control. Lines of about 50, 100, and 200 nsec. delay will be required in various small quantities. Much preparatory ground work in the form of a large collection of manufacturer's data had previously been done. Single samples have been ordered of apparently promising lines from several manufacturers.

Though the requirements for delay time are not closely known, it would seem that fixed delay lines are most appropriate when cost and size are considered. To facilitate possible future replacement and to minimize layout difficulties initially, small, lead-mounted, high impedance units were selected.

A delay line driver, using three transistors in a non-inverting version, has been designed. This driver will produce large, fairly clean, delayed outputs which can likely be used to some extent without further restoration. This end can be accomplished over a rather large range of cable impedance by the change of only one circuit resistor value.

A file report will eventually describe detailed experimental results.

Some work was begun on second generation designs for Drum Select and Write-drive circuits. The attempt was to maintain the operating characteristics of the original circuits while lowering the cost as much as possible. Some interesting, low cost transistors have been found and manufacturer's samples are being tested. A range of possible circuit configurations have been evolved, and tests are being made to evaluate transient characteristics of some of the designs. A file report will be produced describing this work at its completion.

(K. C. Smith, R. L. Cummins)

6. The Arithmetic Control and End Connections

6.1 Layout

All of the chassis in the Q, A and S levels of bays 6F-8F, 6C-8C, 5R-8R, 16FC and 16RC have been laid out on blocks or schematics. This includes the MAU end connections, EAU, EAU decoder including the EAU status memory elements, gate and selector mechanisms for the MAU and EAU, most of the control status memory elements and the inner loops of multiply and divide. A final check of these chassis plus all of the chassis in the Q, A and S levels of bays 1C-5C has been started. This check will accomplish the following: insure that the blocks and schematics agree with the most recent logical representation; insure that the peripheral pin connections are correct and that the signal nomenclature agrees with the logic; insure that the correct bumps are used where specified; and insure that cable drivers and terminations agree. In addition,

during the check, chassis boundaries, transistor numbers, pin numbers, bump designations and node voltages are being added to the logical drawings. Tables have also been added to many of the logical drawings showing the source or destination of a signal entering or leaving the logical block. These tables include chassis name, pin and transistor numbers and a reference to the logical drawing on which the source or destination of the signal may be found. When complete, this system of logical drawings should greatly facilitate the check out process when the chassis are built. This system will be comprised of approximately 80 logical drawings, including those for the Arithmetic Control and the standard cross section logic in the MAU.

If a group of chassis are sufficiently isolated from the rest of the machine because of cable communication or logical function, they are released to the shop as soon as the check is complete and the power requirements determined. The Q, A and S chassis in 16 RC have been released to the shop and the same chassis in 16 FC are ready to be released.

The N and L/N circuits needed for reply and conditional signal distribution in control have been placed in bays 9F-16F, 9R-16R and 17. As soon as the request chassis A9F, A16F, A15R and A10R have been laid out, the layout of individual control points can begin.

(H. Aiso, S. P. Krabbe,
H. Lopeman, J. O. Penhollow)

6.2 Circuit Considerations

A new 9 volt zener bleeder was designed which is capable of performing an OR-AND function at the collector and is hoped to have a fanout of 20. It will be used in the equivalence and exclusive OR circuits at the output of the EAU adder.

(M. Faiman)

The voltage shift calculations and bump requirements for the Arithmetic Control were completed. The shift calculations in the EAU decoder were redone because of the change in the input voltage levels as provided by the bleeder described above.

(H. Aiso)

7. Simplified Instruction Sequencing Control (AC_o)

During July and the first two weeks of August, the logic design for AC_o has been thoroughly checked for compatibility with the units AC_o has to work with. A report describing the operation of AC_o has been prepared (File No. 396).

(Gernot Metze)

8. Advanced Control (A. C.)

During the month the preliminary layout of the Address Arithmetic Unit (A. A. U.) was completed, and described in detail in notes in a loose leaf notebook used to record details of Advanced Control. No additional cable drivers were required other than those expected for the 4 bits which are end-around shifted in going from fast to slow logic at the first stage of the shifter. These 12 chassis are in a state in which the block layout could be done rapidly and wiring begun. This is not planned for a month or two to enable some controls to be placed on these chassis as well, and in case any last minute alterations are required in the few end connections that do exist.

(M. Faiman)

All conditions for the A. C. flow charts have been listed and checked once. Apart from errors and possible simplifications, these flow charts are now complete. Later on, when the order code is assigned, the conditions will be translated into functions of the actual bits which make up the order. Nearly all of the selector and gate mechanisms have been designed. The major ones are the gated entries to Flow Gating, the outputs to Flow Gating, and the priority system for the core memory. The minor ones are the conventional selectors, such as sAB, sAD, sCA, sCB, etc.

The actual design of control points for Advanced Control was begun and is about half-way completed. This includes Sequential Advanced Control and the several autonomous controls. A number of new problems in the design of speed-independent controls have been encountered and solved. In particular, a selector mechanism which is held on only for the duration of the gate which

copies its output into a register has been used, and a direct coupling of two control points with an interlock allowing them to compete for and time-share a device has been designed.

(D. B. Gillies,
R. R. Shively)

During the month, reports were prepared as follows: File No. 395, Advanced Control, by R. R. Shively; File No. 397, A Description of the Operation of Delayed Control in Terms of its Flow Charts, by D. B. Gillies.

9. Magnetic Tape Design Studies

The first two weeks of this period were spent on error-correcting codes--in particular, re-examining codes suitable for use with a 16-channel magnetic tape recorder. In an attempt to reach a better understanding of the encoding process in which it is necessary to guarantee a certain number of 1's in a character or part of a character, a simple conversion was selected for study involving conversion of 5-bit characters to a pair of characters, one base four and one base three excess one. The resulting equations would at least serve as a guide in setting up more interesting conversions.

(R. L. Cummins)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

In August the group carried a reduced program due to the vacation period. H. Guckel continued his tunnel-diode project and came to the preliminary design of a counter which could possibly count up to 3000 mc. Some of his ideas will be discussed in more detail below.

S. Ribeiro found a new phenomenon in his study of saturating transistors: it seems that transistors become collector controlled devices at very high current densities. This phenomenon of "super saturation" is under further investigation. A full report on the results will be given in the September Monthly Progress Report.

G. Ujhelyi treated the transient response of a simplified Schmidt-Trigger flipflop in view of a phase plane analysis. Some results will be given below.

2. Tunnel Diode Work

The following arguments are based on experience and theoretical considerations performed in July and August and constitute a summary of experience gained in working with the Germanium RCA IN3130 tunnel diode.

Switching Performance

The inherent switching speed of the device is in the neighborhood of 200 μμsec. However, this is to be taken quite skeptically. First of all the voltage supply should have truly zero impedance from DC to 2500 MC or higher. Secondly, the component should behave as specified and thirdly, some overcurrent standard must be used. Since the inherent inductance of the circuit is always involved, it is possible to obtain pulse stretching with a circuit as shown in Figure 1. A measure of this effect may be obtained by using the arrangement of Figure 2:

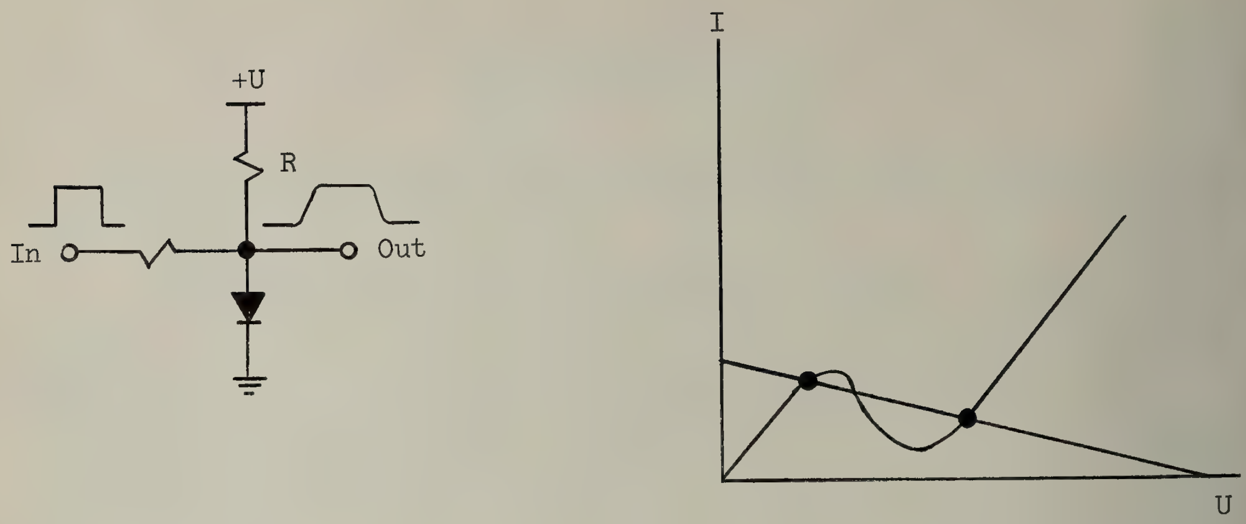


Figure 1

Pulse Stretching

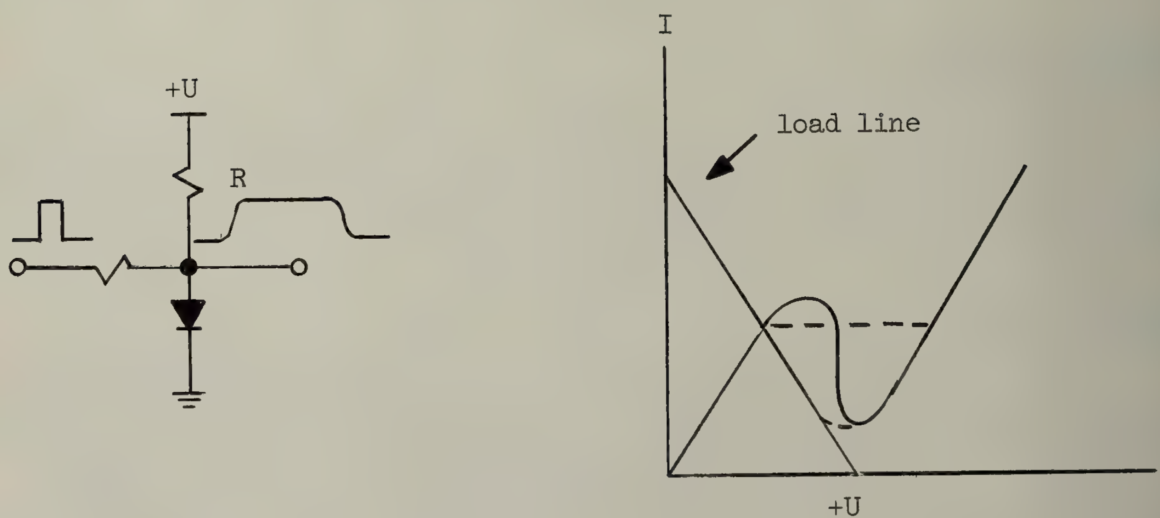


Figure 2

Choice of R for Uniform Stretching

However, with a properly designed circuit, and this is to include layout but not necessarily interconnection, a relaxation time of 1 nanosecond seems to be sufficient. (See later comments.)

Overall System:

The following definitions will be used in the systems design

1. Directivity is the property of a circuit to transfer, transform or store the information of its inputs in such a way that interaction between inputs will not cause a change in one or more inputs directly nor will the output effect the inputs in any direct way.

2. Asynchronous operation is the operation of a set of circuit complexes without the presence of a central pump signal, which controls the information advance.

In order the explain the proposed system of circuits the somewhat unusual aspects of tunnel diodes will be emphasized. Consider the circuit of Figure 3.

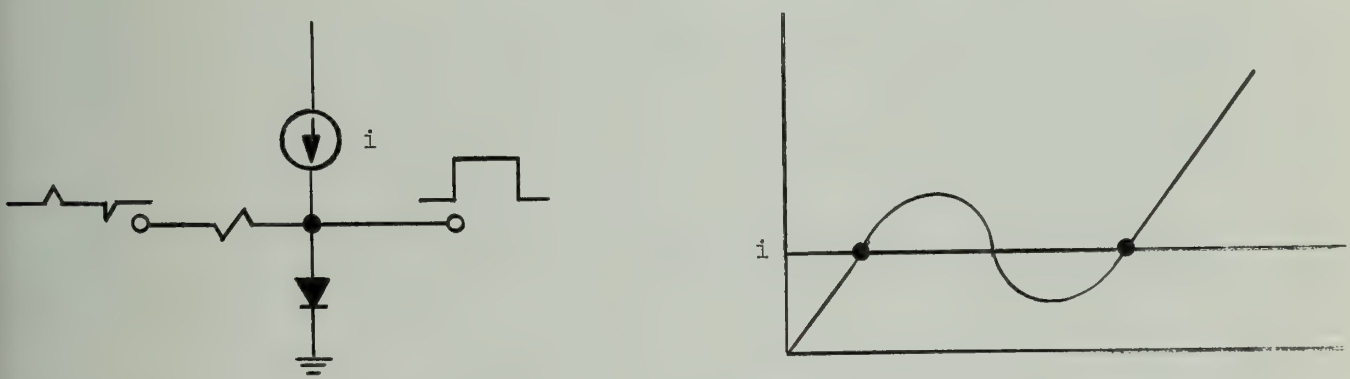


Figure 3
Latch Circuit

The circuit is of course a latch, hence a memory element. If several of these circuits are coupled together, as for example as shown in Figure 4,

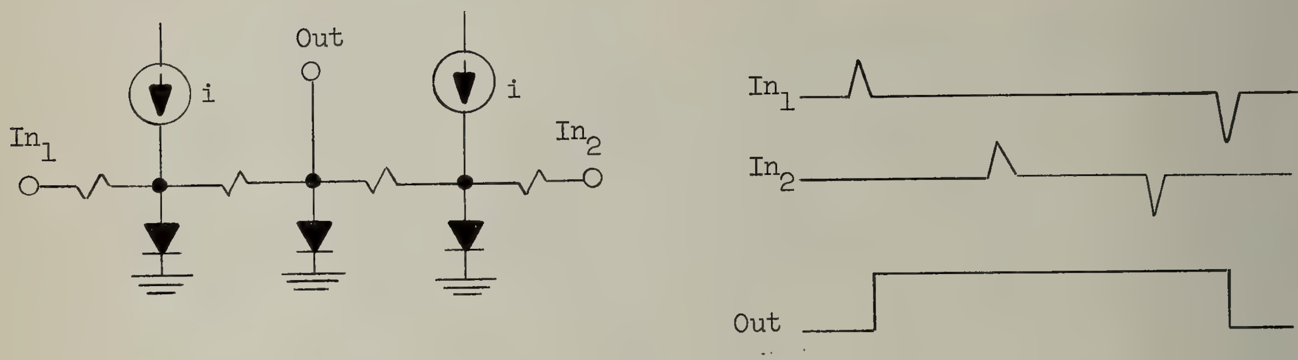


Figure 4
Memory OR

we would get a set of circuits with memory performing a sort of "OR" function. It is then clear that a DC representation can be obtained, as for example the "OUT" above, even though AC-interstage coupling is used. This in turn means that DC-design will not be too difficult. Furthermore, if it is assumed that the tunnel diode during "up to threshold" switching is essentially a capacitor, the coupling system of Figure 5 is feasible so that switching is voltage controlled.

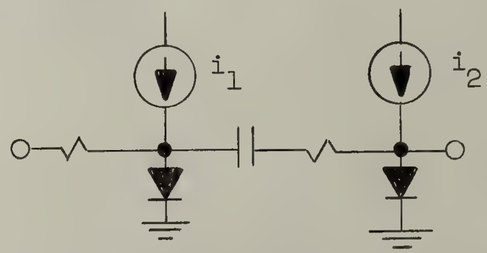


Figure 5
Capacitive Coupling

Since we are dealing with a latch type circuit, the reset problem occurs. This may be solved by an external clock, which is not desirable, or the method described in the June report. Figure 6 shows the setup.

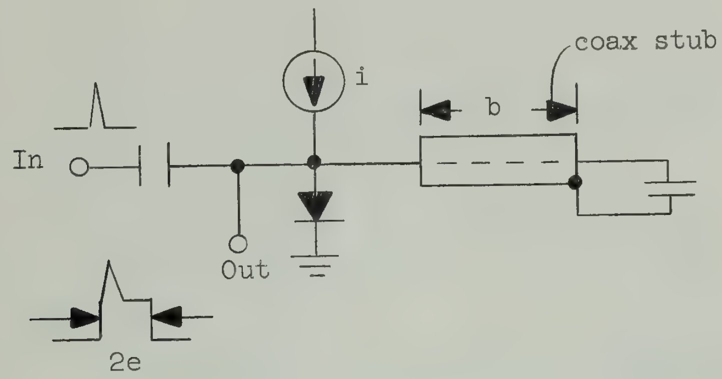


Figure 6
Autopump Latch

In contrast to the memory logic elements above, this type of circuit will be called reset logic. A third type of circuit is possible which uses a combination of both elements and both types of coupling. In order to explain these ideas a very simple example is shown in Figure 7. It is assumed that the initial state is a = 0, b = 0. The most attractive of these circuits is the one using reset logic. The argument for this is the necessity of only positive going pulses, which is very agreeable if a partial DC-coupling is desirable.

In the following figures some aspects of these types of circuits are evaluated as far as logical design is concerned. The end result is the scale of 10 counter. It has, in any realization, the property of uniform time use of the symmetrical binaries, that is to say, each binary switches at a fifth of the input frequency. However, since each "OR" input from the signal to be counted changes at a very high speed, the counter may very well be limited by the set-reset time of the "OR" circuit. But this is not so serious since the output should not change.

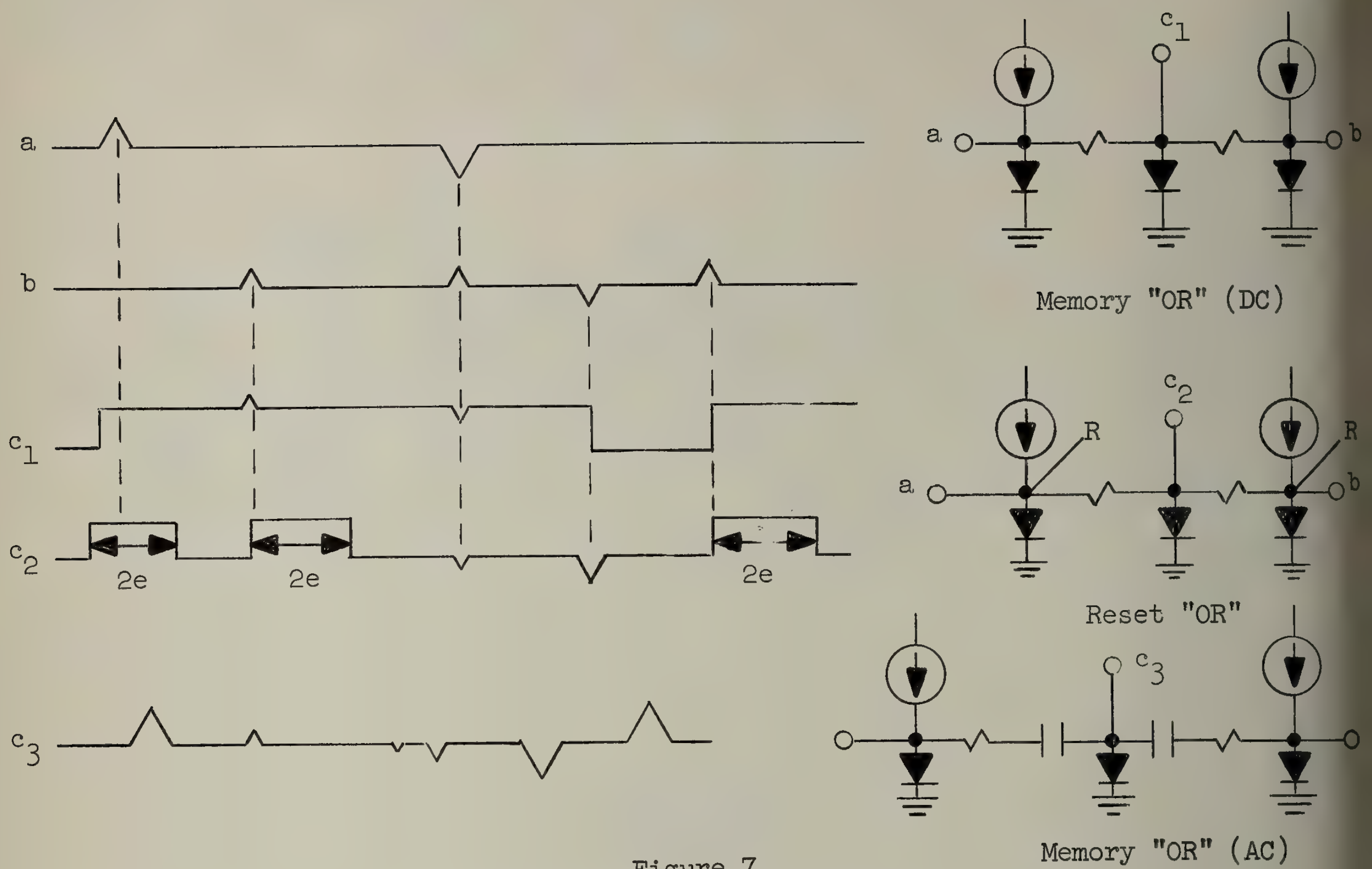


Figure 7

Three Types of "OR" Circuits

Figure 8 shows how a symmetrical flipflop can be formed out of 2 latches (see Figure 3) coupled by a bidirectional NOT in the form of a 1:1 coaxial transformer.

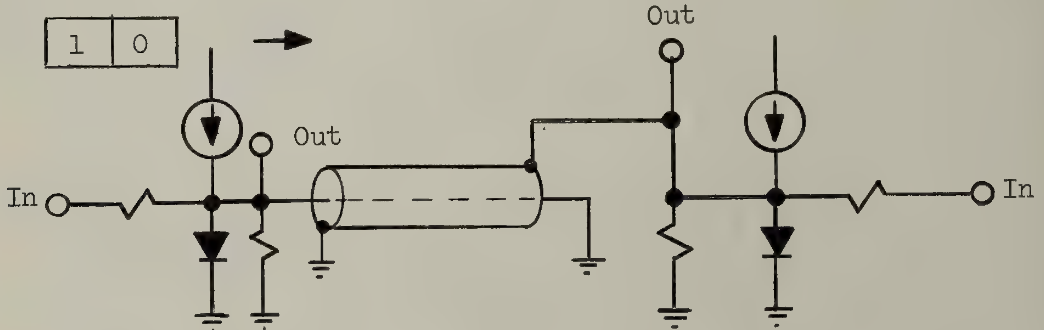


Figure 8

Symmetrical Flipflop

Figure 9 shows a scale of 10 counters using the flipflops of Figure 8 and a 3 input OR of the type shown above.

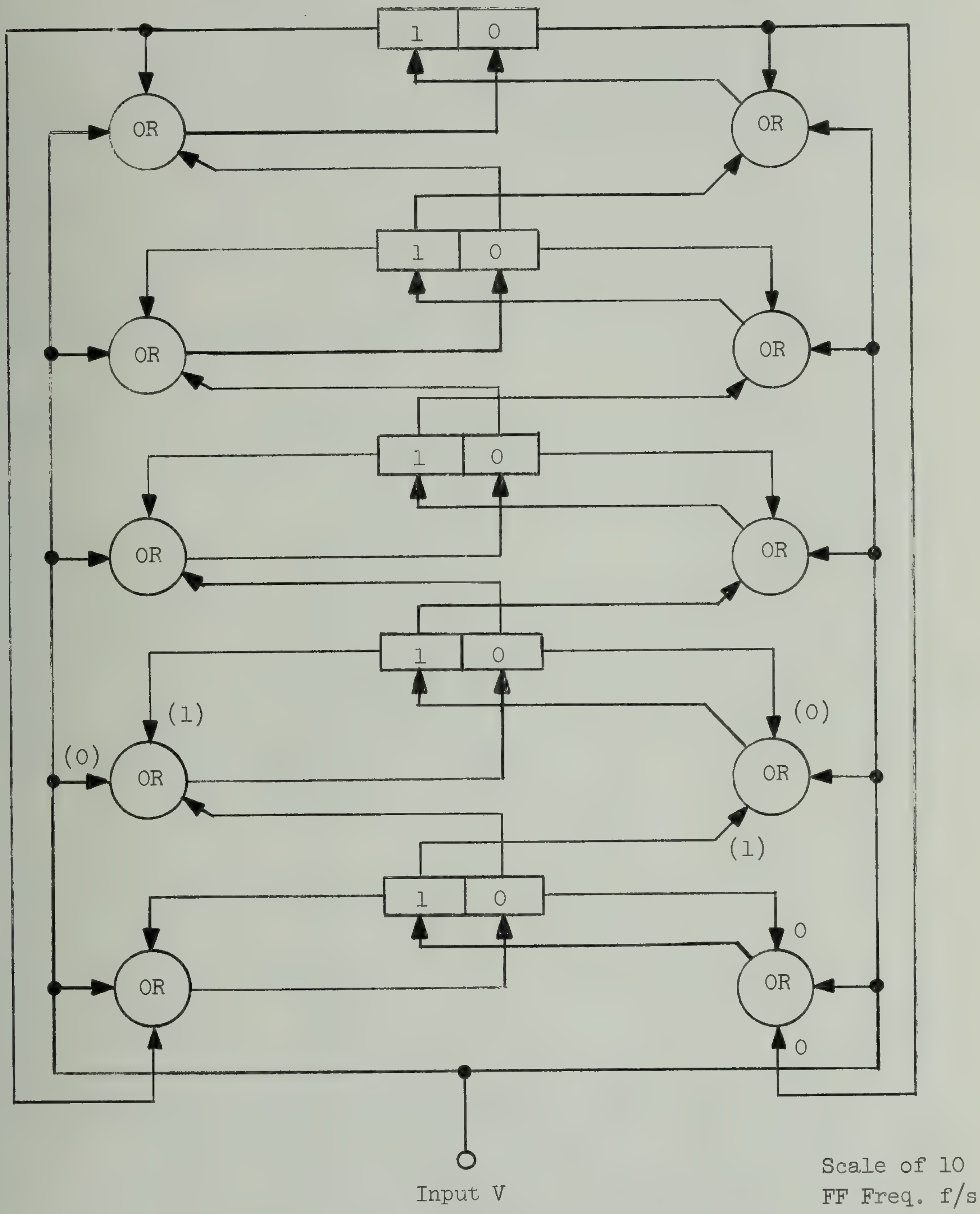


Figure 9

Scale of 10 Counter

3. Phase-Plane Diagrams

A very simplified flipflop of the type shown in Figure 10 was studied in view of the calculation of switching times from phase-plane trajectories. Note that the flipflop has only two resistors. C_R and C_K are the only stray capacitances one has to take account of in a simplified theory. It is desired to show that the phase-plane diagram gives approximately for the $0 \longrightarrow 1$ switching time $\tau_{0 \longrightarrow 1}$

$$\tau_{0\longrightarrow 1} = \frac{C_R\,[V - (R + K)\,i_0]}{\frac{V}{K + R} - i_0} + C_K K + \frac{(K + R)\,C_R\,[-V + K\,(i_0 + I_0) + Ri_0]}{K I_0}$$

where the notation is explained in Figure 10.

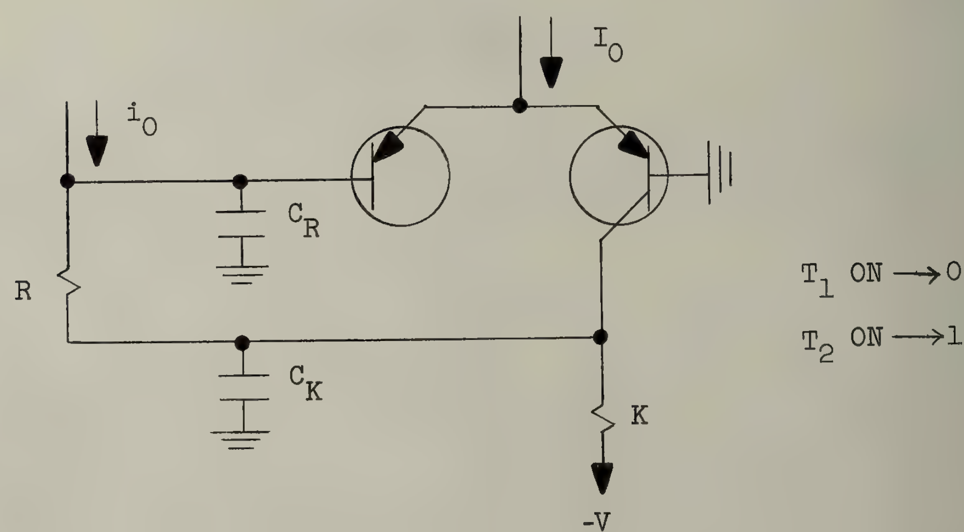


Figure 10

Simplified Flipflop for Switching Analysis

PART III

DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

AUTOMATIC REDUCTION OF DATA FROM BUBBLE CHAMBER PHOTOGRAPHS

1. Pair-Count Scoring of Local Domains on Bubble Chamber Negatives

The factor analysis of pair counts on local domains of bubble chamber negatives (plates 4 and 5) is now complete. Domains were both humanly and randomly selected. A final write-up is in progress.

2. Sampling of 8-Bit Rectangular Domains from Bubble Chamber Negatives

Regular rectangular grids were imposed on two plates (numbers 4 and 5) and all 8-bit arrays (8 x 1, 4 x 2, 2 x 4, 1 x 8) cut out were examined. The frequency of occurrence of each pattern for given rectangular grid (say 2 x 4 domains) were tabulated. Patterns were sorted in order of decreasing frequency of use. The 60 most frequent patterns were common (with few exceptions) to both plates, and approximate order in frequency listing preserved. Preliminary estimates of the average number of bits per symbol (e.g., 2 x 4 subraster pattern) is approximately 4. Computation of entropy H where

$$H = -\sum_{n=1}^{256} p_i \,\ell n\, p_i$$

with p_i = frequency of occurrence of i^{th} pattern is in progress.

3. Tentative Logical Realization of a Pattern Recognition Computer

A preliminary draft of a report describing a digital general purpose pattern recognition computer has been prepared. Some appropriate tasks for the unit arise in the automatic scanning of bubble chamber negatives, library microfilm, and serial reconnaisance photographs. The logical design proposed features

a large word size ($\sim 10^4$ bits) with all bits of the word processed in parallel in an iteratively constructed two-dimensional array. Extensive facilities for performing local bit logic (template matching, edge detection, local smooting, n-tuple tallies in local areas, etc.) are provided. Sensing arrangements allow for pyramidal projective encoding, track coordinate readout (in parallel) and, when necessary, intensive examination of selected sub-areas of the image. A buffer memory of 16 words can be provided.

The logical design bears little resemblance to a conventional digital computer. In fact, many tenets of contemporary (arithmetic) design are violated, e.g., by the large word size, the two-dimensional register organization, and the use of physical translation of bit patterns rather than address modification. These variances from conventional computer practice are well justified, we believe, as pattern recognition shares little in common with arithmetic computation.

The logical design proposed is to be considered a first tentative speculation; detailed simulation studies are in progress.

(B. H. McCormick, J. Stein)

PART IV

MATHEMATICAL RESEARCH USING COMPUTERS

(Supported by NSF Grant G16489)

Two research problems involving the use of ILLIAC were studied this summer. The first concerned a hunt for counterexamples to a conjecture put forth by Polya and Schoenberg in 1957 (Pac. J. Math.). This conjecture is quite important in conformal mapping theory and had never been either proved or numerically tested. As a result of a quite extraordinary programming effort by three of the summer students (Messrs. Horn, Shapiro, and Miller) the program was completed in mid-August and run quite extensively on the computer. No counterexample was found but the effort must be counted a fine success anyway since the plausibility of the conjecture was greatly enhanced by the search. Professor Schoenberg has asked me to submit a summary of the calculation of MTAC, and this will be done presently.

The second problem, which was executed jointly by Messrs. Merrow and Reed, involved carrying out a Gauss quadrature on the Riemann zeta function. This was considerably more straightforward than the calculation mentioned above. Some of the results of this calculation will appear in a note being prepared for MTAC by Mr. Reed.

(Herbert S. Wilf)

PART V

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of August, no new routines were added to the Illiac Library.

Illiac Usage

During the month of August, specifications were presented for 28 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2023. Numbers followed by T are for theses.

2023 Communications. Public Opinion and Persuasion Survey. Panel interview data and semantic differentials for about 220 subjects are to be analyzed for a study of the relations between persuasion variables and educational TV viewing. Chi squares and distance scores will be obtained for various subgroups, based on changes over time. A correlation matrix will be computed, first finding change over time by matrix subtraction, and then by intercorrelation with demographic variables.

2024 Chemistry. Calculation of Slater Integral. The problem is to evaluate the function

$$Im(\theta) = \frac{1}{\Gamma(m+1)} \int_0^{\infty} \frac{x^m e^{-x}}{1 + \frac{x^m}{\theta}} dx$$

where m = 1, 1.5, 2, 2.5, ..., 15,
$\log_{10}\theta = m - 7$ to $m + 4$

$Im(\theta)$ expresses the pressure dependence of the rate constant of a unimolecular reaction involving n Slater degrees of freedom, where n = 2m + 1. The method used will be Simpson's rule for numerical integration.

2025 Theoretical and Applied Mechanics. Pada with Continuous Supports. Computations for a previous study, Problem Number 1654 (A57), were performed on Illiac. This involved an unbalanced rigid cylinder spinning in bearings which were supported by linear springs and viscous damping elements on a rigid mass which itself was spring supported. This problem is similar, except that the massless springs supporting the spinning cylinder are replaced by flexible cantilevered beams having a continuous mass distribution. The response function for the beam has been computed analytically. For this study, the numerical computation involves evaluating this function in place of the spring constants.

2026T Physics. Harmonic Oscillator. A pilot harmonic oscillator problem is to be solved using Illiac to provide experience in numerical integration of differential equations prior to the execution of a thesis problem in this area.

2027 Coordinated Science Laboratory. Research on Tunnel Diode. The purpose of this research is to analyze tunnel diode circuits and then to synthesize the new specific circuit by using the tunnel diodes. In order to do this research, it is necessary to solve non-linear differential equations.

2028 Chemistry. Monte-Carlo Diffusion Kinetics. This study is related to previous studies described under problem numbers 1031, 1568 and 1647, which are concerned with the diffusion-kinetic equations of radiation chemistry. These differential equations assumed a continuous distribution of reactive species, while actually only a small number of particles may be involved. Therefore, it is proposed to investigate the effect of having only a few reactive particles by a Monte-Carlo simulation of the diffusion-reaction process. Particles are to be placed on a three-dimensional lattice and allowed to execute random walks. Two particles sufficiently close together will have a certain probability of reacting. Particles can also "disappear" by reacting with solute (assumed uniformly distributed) or by diffusing outside the lattice boundaries. Information thus obtained on the fraction of particles disappearing by various means can be compared directly with the results of solving the differential equations. It is particularly important to study these fractional yields as a function of the number of particles

in order to find out how many particles are necessary to have a good approximation to the differential equations.

2029T Digital Computer Laboratory. Boundary Treatment of Dirichlet Problem for Laplace Equation. It is desired to find U such that

$$U_{xx} + U_{yy} = 0 \text{ in } R,$$

and

$$U = f \text{ on "e" where e is the boundary of } R.$$

R will be the region inside an annulus whose outer circumference is divided into eight equal parts, each being kept at positive or negative potential alternately, and the inner put to ground. The electrostatic potential satisfies the Laplace equation. A closed form solution is not feasible in such a case. The problem will be solved by finite difference schemes, using the five point formula for the value of U at any point P in terms of its neighbors.

The different methods of boundary treatment which will be adopted are:

1. Polynomial of degree zero.
2. Polynomial of degree one in one variable.
3. Polynomial of degree two in two variable.

2030T Sociology. Influence of Social Status and Social Mobility on Fathers' Rankings of Ten Life Goals. A sample of 370 fathers ranked a list of ten life goals in order of importance as they perceived them and as they hoped their son(s) or any boy would rank them. The fathers were then classified on the basis of their social status and the basis of their social mobility attitude. An attempt was made to compare the status-mobility groups with respect to the rank order assigned by each group to the ten life goals. However, preliminary analysis indicated that status-mobility groups could not be compared on the basis of the assumption that one dominant rank order of the ten goals could be used to characterize each group.

To investigate further, it is proposed to perform factor analyses on a sub-set of the total available data in order to determine if this technique would reveal (a) the different dominant rank orders within status-mobility groups and (b) the factors underlying the dominant rank orders.

2031 Psychology. Factors in Persuasion. The research involves identification of personality factors related to persuasibility and to immunizability against persuasion. Data have been collected for about three hundred persons on ninety variables which include measures of personality and measures of susceptibility to persuasion in various experimental situations. Illiac will be used first to obtain correlations, then principal axes factors, and finally a Varimax rotation.

2032 Agricultural Economics. Revision of KSL 4.50. The program KSL 4.50, Limited Information Estimation, Single Equation, is used in many problems in this department and others. This program involves inverting several small matrices, which, under some combinations of circumstances, cause difficult scaling problems. It is believed that the internal scaling for the calculation of the standard errors of the estimates can be improved. To check this program will require using it with several sets of data for which the answers are known.

2033T Civil Engineering. Stresses in Multi-Beam Highway Bridges. To prepare information for this thesis topic, it will be necessary to generate and solve a considerable number of simultaneous linear algebraic equations. For some of the solutions, as many as 33 equations will be involved.

This thesis will be an extension of a previous study by A. S. Arya, entitled "Lateral Distribution of Concentrated Loads on Multi-Beam Highway Bridges".

2034 Agricultural Economics. Successive Differences and Variances. The problem involved is the estimation of random variation in time series of Illinois crop yields, prices, and income per acre for the time period 1927-1960. Estimates of the past random variation in a time series of crop yields can be used to estimate variation from trend in future years. The ultimate use will be in the formulation of expectation models which can be used as a basis for farm management, marketing, and agricultural policy decisions.

Data on yields, price, and income per acre for corn, soybeans, oats, wheat and hay will form the three different types of series. For each commodity

in each type of series, data will be assembled for each county in Illinois for the 1927-1960 period. The variate difference method will be used to estimate the random variation in the series.

2035T Petroleum Engineering. Surface Energy of Solids. Many sets of experimental data F(x) can be fitted to the equation, $y = a_0 + a_1 \ln x$, by the method of least squares. Values for a_0 and a_1 will be found, and then estimates of y can be compared to the observed values of y.

2036 Psychology. Effects of Infantile Experience on Adult Behavior in Rats. This study is to determine how different infantile treatments affect adult rat behavior.

The infantile treatments include handling and shocking baby rats for a ten day period. The measures of adult behavior include a drinking test under water deprivation, an escape threshold shock test, and a survival test in which the rats swim until drowned. The question is whether shock and handling enable the rat to adapt to new and stressful conditions better and, if so, which technique is most effective. The method of analysis will be analysis of covariance using routine K15.

2037T Physics. Superconducting Critical Field Curves. For comparison with theory, it is necessary to compare experimental values of specific heats, derived from measurements of critical fields in superconduction. Illiac will be used to make detailed fits to the experimental data, and the results will be used to compute appropriate values of the specific heat.

The specific heat is computed from the slope of the critical field curve vs. temperature, by doing either a high-order fit to the whole range of t-values, or by doing linear fits to small segments of the curve. Values of the specific heat will be computed from the coefficients of the resulting least-squares polynomial.

2038 Physics. Numerical Integration of Spherical Functions. Illiac will be used to integrate a complicated function which has spherical Bessel and Neumann functions for a large range of orders and arguments. The results will be used to compare theoretical calculations with experimental values using parameters derived from solid state physics experiments.

2039T Physics. Evaluation of the Transmission Integral. In experiments involving the Mössbauer effect, the very narrow resonance lines resulting from transitions from low-lying nuclear levels can actually be observed. The line shapes obtained in such experiments are complicated functions of the emission and absorption spectral shapes.

A theory, based on the assumption that the emission and absorption spectra have Lorentz shapes, has been developed by performing the required numerical integration on Illiac. However, the results of this theory are not in good agreement with some of the experimental data. In these cases, measurements seem to indicate that the actual transition line shapes are not true Lorentz curves, but may have a Gaussian shape. Consequently, it is necessary to evaluate an integral of the form

$$P(x,T) = \int_{-\infty}^{\infty} dy e^{-(y+x)^2 - Te^{-y^2}} \quad (1)$$

The desired information about the line shape can be obtained from the sum

$$F(x,T) = \sum_{n=1}^{\infty} \frac{(-T)^n}{n! \sqrt{n+1}} e^{-\frac{n}{n+1} x^2} \quad (2)$$

which is obtained by expanding the second exponential in (1) and integrating term-by-term. Since this sum converges slowly for large values of T, computer evaluation is required.

2040 Statistical Service Unit. Analysis of Teacher Training Program. Ten measurements were taken on 670 students enrolled in the teacher training program at Illinois State Normal University during their junior year. These measures include grade point average, sex and a number of predictive measurements by the MMPI and ACE tests.

Illiac is desired to compute first order correlations, multiple correlations with grade point average as the dependent variable, and to extract approximately three factors from the correlation matrix.

2041 Physics. Reciprocal Gamma Function. Existing tables of the reciprocal gamma function are tabulated only within a restricted region and with relatively coarse subdivisions. The object of this problem is to compute a table of reciprocal gamma functions for complex arguments which will double (approximately) the accuracy of existing tables, using the expansion

$$\frac{1}{\Gamma(z)} = \sum_{k=1}^{23} C_k \, Z^k,$$

where the coefficients are given by Bourguet (Acta Mathematica, Vol. 2(1883)). The relation

$$\frac{1}{\Gamma(z+1)} = \frac{Z}{\Gamma(z)}$$

will be used to generate further values.

2042T Electrical Engineering. Electromagnetic Problem of Curved Wire. This problem has been formulated in terms of an integral equation, which transforms the current distribution in the wire onto the tangential electric field at the boundary. The kernel function is of a singular type and is quite complicated. It is proposed to evaluate the kernel function numerically.

2043 Institute of Communications Research. Simulations of International Relations. Fourteen groups of 21 students each, dividing into seven "nations" of three each, in a controlled laboratory situation, carried on inter and intra-national affairs. All of their communications were monitored. At three different stages of the experiment, subjects rated eight semantic differential forms (the other "nations", etc.).

The present analysis will examine the factor structure and compare differences in the groups.

Statistical procedures will include the calculation of means for each group, correlations and factor analyses over the 14 replications for each of the three time periods. Sums of differences will be calculated and analyzed in working with the "d" statistic.

2044T Electrical Engineering. Study of Nonlinear Systems. The problem under consideration is the analysis and synthesis of a nonlinear system subject to random input functions. For the classes of systems and inputs being considered, the output can be expressed in a power series (in powers of time). The coefficients in the power series depend on the statistical moments of the input.

The relationship determining these coefficients is recursive (the value of each coefficient depends on those already calculated). The relationship is an adaptation of the Cauchy product which results when two power series are multiplied. Illiac can be used to perform these recursive computations to determine the coefficients of the power series. Then the output function can be integrated over a time interval to determine a figure of merit for the system.

The synthesis procedure is to use the steepest descent method to determine the "best" choice of coefficients in the nonlinear system. The criterion for optimization will be the figure of merit calculated above. In the examples to be used in this study, only two constants in the nonlinear system will be allowed to vary; thus, the minimization will involve only two variables.

2045T Sociology. Sociological Studies within City Blocks. Basically, the problem is the following: Given a two-dimensional array of city blocks $\{b_{ij}\}$, with each block b_{ij} characterized by n numbers, a_{ij1}, a_{ij2}, ..., a_{ijn}, find that partitioning of $\{b_{ij}\}$ into P contiguous areas which maximizes homogeneity (i.e., minimizes variance of a_{ijk}'s) within the areas.

A method for finding an approximate solution to be tried at present consists roughly of (a) identifying the already existing homogeneous groups of blocks (i.e., areas in which $|a_{i_1j_1k} - a_{i_2j_2k}| \leq \epsilon_k$ for any two b_{ij}'s in the area); and (b) adding the remaining blocks to contiguous areas by relaxing the ϵ_k restrictions.

2046 Dairy Science. Inbreeding in Goats. The University of Illinois goat flock is being selected for milk production. To analyze the selection data, it is necessary to have coefficients of inbreeding and relationship. Illiac will calculate these coefficients.

2047T Geology. Hydrometer Analyses of Pleistocene Sediments. In this investigation, samples of glacial deposits from Alberta, Canada are being studied. The character of these samples will be investigated to determine the textural and mineralogical properties of the material in order to obtain a more complete interpretation of the glacial-geology development of Central Alberta. The grain size analysis of the silt and clay fraction of these glacial materials is one of the methods used to obtain this information because it is an aid in the determination of their depositional environments.

The grain size distribution of the silt and clay portion of 52 samples is determined by hydrometer analyses which are briefly described below.

Each sample is mixed with water, thoroughly shaken in a sedimentation cylinder, allowed to settle. The density of the suspension is determined periodically with a soil hydrometer. Certain simple formulas based on Stoke's Law convert the density information to the percentage of soil smaller than a certain diameter. The density of the suspension changes with time since the larger particles settle faster than the smaller ones. A series of readings at various times gives the size distribution of the sample.

The formulas used in the computation of the analysis are as follows:

$$\text{Percentage} = (a)D/W \times 100$$

W = weight of whole test sample
D = corrected hydrometer reading
a = correction factor for specific gravity

$$\text{Diameter} = K\sqrt{L/t}$$

D = diameter in mm
L = effective depth in cm
t = elapsed time in minutes
K = factor that varies with temperature

With the basic data: weight of sample, elapsed time, hydrometer reading, and the temperature of suspension at the time of reading, the digital computer can select values of R, K and L and solve the equations.

2048 Illinois Geological Survey. Trace Elements in Argillaceous Sediments. This problem will compute covariance matrices, a correlation matrix and solve a set of seven simultaneous equations. These calculations are required for the completion of a study of trace elements in marine and fresh water argillaceous sediments.

2049 Psychology. Test Item Parameters and Prediction of Test Score Moments. It can be shown that the third, fourth, etc. moments of a distribution of test scores may be obtained directly from knowledge of certain inter-item relationships. Although such relationships are known, there is no evidence of their importance in influencing the moments of empirical data. The proposal here is to take certain score distributions (abilities and personality tests) and study the effect of certain higher order relationships (third order correlations) upon the third moment of the test score distributions.

2050T Mechanical Engineering. Weight Optimization of Radiation Fins with Mutual Irradiation. It is the objective of the thesis to develop a procedure by which optimum propositions of radiation fins, arranged symmetrically around a circular cylinder at uniform temperature T_o, could be obtained. The fins under investigation are either rectangular or triangular in cross section or circumferential ones. In each case, the equation to be solved is a nonlinear integro-differential equation, the solution of which does not seem possible at this stage. Instead, it was decided to use finite difference techniques. In what follows, the equations pertaining to the rectangular fin case are discussed.

The fin length is divided into M subdivisions, energy balance is performed on each of the elemental subdivision and the following equations are obtained for a specific fin length 1.

$$G_i = \theta_i^{4} - \zeta\left[\Delta^2 \theta_i\right] - \theta_e^{4}\left[\frac{1-r_e}{\epsilon} F_{m,se}\right]$$

$$-\theta_e^{4}\left[\frac{\epsilon - (1-r_e)}{\epsilon}\right]\sum_{n=1}^{M} \Delta F_{n,se}\, \Delta F_{i,n}$$

$$+\sum_{n=1}^{M}\left\{(1-\epsilon)\,\zeta\,\Delta^2 \theta_n - \theta_n^{4}\right\} F_{i,n} = 0 \qquad (1)$$

$$i = 1, 2, \ldots M$$

where

$$\theta = \frac{T}{T_o} = \text{Dimensionless temperature}$$

$$\Delta^2 \theta_i = \theta_{i-1} - 2\theta_i + \theta_{i+1}$$

θ_e = Equivalent space radiation temperature

ζ = Dimensionless parameter

$$= \frac{KA_p M^2}{2\epsilon\sigma T_o^{\,3} \ell^3}$$

re = Reflectivity

K = Thermal conductivity

A_p = Cross sectional area of the fin

ϵ = Emissivity

σ = Stefan Boltzman Const.

M = Number of subdivisions

T_o = Fin root temperature

ℓ = Fin length

$\Delta F_{m,n}$ = Configuration factor of the m^{th} element w.r.t. n^{th} element.

In order to optimize the fin system, LaGrange's Method of Undetermined Multipliers is to be used; which when used, gives rise to equations of the following form:

$$\sum_{i=1}^{M} \frac{\partial G_i}{\partial \theta_j} \lambda_i + \frac{\partial (NQ)}{\partial \theta_j} = 0 \qquad j = 1, 2, \ldots M \qquad (2)$$

where λ's are LaGrangian multipliers and (NQ) is the total amount of heat transferred by the fin system.

and $$\sum_{i=1}^{M} \frac{\partial G_i}{\partial \ell} \lambda_i + \frac{\partial (NQ)}{\partial \ell} = 0 \qquad (3)$$

Thus, in order to optimize the fin system, it is necessary to solve (2M+1) [(1), (2), (3)] equations, nonlinear in nature.

It was decided to use Newton-Raphson method of iteration for solving these (2M+1) equations. This necessitates solving (2M+1) simultaneous linear equations at each cycle of iteration.

M is chosen as 15.

The procedure is to be repeated for N = 2, 3, 4, 5, 6 and 8, where N is the number of fins arranged symmetrically about the cylinder.

Table I shows the distribution of Illiac machine time for the month of August.

TABLE I

	Hrs:Min	
Scheduled Maintenance	63:14	
Unscheduled Maintenance	33:27	
Drum Engineering	4:39	
R. A. R.	:17	
Leapfrog	3:05	
Wasted	:51	
Library Development	6:26	
Demonstrations	:53	
Classes	40:00	
		152:52

Use by Departments

Aeronautical Engineering	5:23
Agricultural Economics	17:46
Agronomy (00 15-15-306)	1:01
Agronomy (00 15 65 330 38)	1:11
Agronomy	1:12
Animal Science	4:15
Astronomy (NSF-G-14834)	1:07
Bur. Econ. and Bus. Res.	8:40
Chemistry (NSFG-5907)	9:32
Chemistry	43:51
Civil Engineering (NSFG 6572)	2:59
Civil Engineering (AASHO ROAD TEST)	2:16
Civil Engineering	139:47
College of Medicine	3:51
Coordinated Science Lab. (DA-36-039-SC56695)	69:21
Digital Computer Lab. (NSF GRANT 9503)	:56
Digital Computer Lab. (NONR 1834(27))	2:14
Digital Computer Lab. (US TR AEC-1018)	14:12
Digital Computer Laboratory	:44

Economics (NSFG 7056)	3:16		
Electrical Engineering (NONR 1834(22))	6:13		
Electrical Engineering (AF 33(616) 6079)	:03		
Electrical Engineering (NASA-NSG 24-59)	5:39		
Electrical Engineering (NOBSR 64723)	1:04		
Electrical Engineering (AF 7043)	7:16		
Electrical Engineering (AF 4622-25-314)	:37		
Electrical Engineering (SL 85173)	2:13		
Electrical Engineering	2:12		
Finance (IHR-71)	:13		
Food Technology (50-343)	2:17		
Food Technology	3:56		
Geological Survey	:16		
Geology	:04		
Inst. of Comm. Res. (44-28-20-378)	1:54		
Inst. of Comm. Res. (USPHM-3941 46-28-20-364)	1:36		
Institute of Communications Research	:27		
Inst. for Res. on Excep. Children (HE WSAE 8204)	:14		
Institute of Labor and Industrial Relations	3:04		
Mathematics	3:10		
Mechanical Engineering (DA-11-022-ORD 1980)	:34		
Mining and Metallurgical Eng. (TRUS AF 6770)	:34		
Mining and Metallurgical Eng. (CML 51F)	1:00		
Mining and Metallurgical Eng. (Pet. Eng.)	:50		
Mining and Metallurgical Engineering	3:53		
Office of Instr. TV (OE 7-11-107.00)	4:16		
Office of Instructional Television	:41		
Physical Education	:24		
Physics (ORD 1001)	:06		
Physics (NONR 1834(05)A)	:12		
Physics (GEN. ELEC. FELLOWSHIP)	:07		
Physics (NAVY C)	:08		
Physics (COMPTON NON-RECURRING)	:16		
Physics	41:07		
Psychology (MD 2060)	4:59		
Psychology (AF 49(638)371)	2:28		
Psychology (AF 41-657-279)	2:07		
Psychology	93:23		
Sociology	3:00		
State Water Survey (DA-36-039-SC 75055)	7:16		
State Water Survey (NSF-G6572)	5:48		
Theoretical and Applied Mechanics (NOBS 72069)	:10		
Theoretical and Applied Mech. (DA-11-070-508 ORD)	15:59		
Theoretical and Applied Mech. (DA-01-021ORD11878)	3:26		
Veterinary Physiology	:05		
Williams College	6:59		
		591:08	
			744:00

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Reader	4
Punch	1
Arithmetic	2
Control	2
Input-Output	1
Memory	2
Drum	8
Unknown	3
Other	4
Total	27

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/1/61	21:28	:00	2:32	0		:00	:00	0
8/2/61	20:41	:49	2:30	3	(1) Reader control chassis. (2) Unknown. (3) Unknown.	:00	:24	0
8/3/61	20:49	:00	3:11	0		:00	:23	0
8/4/61	19:41	1:49	2:30	2	(1) D. C. marginal. (2) Input-output error.	:00	:00	0
8/5/61	22:05	1:55	:00	2	(1) Control error. (2) Unknown.	:00	:10	0
8/6/61	23:49	:11	:00	1	(1) Drum failure.	:00	:00	0
8/7/61	16:04	4:20	3:36	2	(1) Filament voltages too high. (2) Drum failure.	:00	:56	1
8/8/61	19:24	1:19	3:17	2	(1) Reader "K" error. (2) Adder pos. 35.	:00	:19	0
8/9/61	21:18	:01	2:41	1	(1) Drum failure.	:00	:00	0
8/10/61	20:18	:00	3:42	0		:00	:08	0
8/11/61	21:33	:00	2:27	0		:00	:04	0
8/12/61	16:11	7:49	:00	3	(1) Water leak into power supply room; forced to shut down until taken care of. (2) Broken lead in R_3. (3) Drum failure.	:00	:00	0
8/13/61	24:00	:00	:00	0		:00	:12	0
8/14/61	21:30	:25	2:05	1	(1) Memory failure pos. 2^{-18}.	:00	:04	0
8/15/61	21:00	:08	2:52	2	(1) Reader "J" light bad. (2) Clutch on reader "D" bad.	:00	:00	0
8/16/61	20:38	:00	3:19	0		:00	:03	0
8/17/61	20:37	:00	3:23	0		:00	:00	0
8/18/61	21:49	:00	2:03	0		:00	:08	0
8/19/61	23:59	:01	:00	1	(1) Punch error.	:00	:00	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/20/61	19:55	4:05	:00	1	(1) Drum failure.	:00	:02	0
8/21/61	21:47	:00	2:13	0		:00	:00	0
8/22/61	21:00	:00	3:00	0		:00	:00	0
8/23/61	14:41	7:17	2:02	1	(1) Drum failure.	:00	:00	0
8/24/61	21:11	:19	2:30	1	(1) D. C. marginal error.	:11	:00	0
8/25/61	20:16	1:27	2:17	1	(1) Memory failure pos. 2^{-30}.	:00	:00	0
8/26/61	22:48	1:12	:00	1	(1) Drum failure.	:00	:00	0
8/27/61	24:00	:00	:00	0		:00	:00	0
8/28/61	21:23	:31	2:06	2	(1) Reader failure, reader "F". (2) Drum failure.	:00	:00	0
8/29/61	20:50	:00	3:10	0		:00	:00	0
8/30/61	20:37	:00	3:23	0		:00	:00	0
8/31/61	21:33	:00	2:27	0		:00	:00	0
TOTALS	646:55	33:38	63:16	27		:11	2:58	1

PART VI

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New 650 Codes

During the month of August, two new routines were added to the Digital Computer Laboratory 650 Library.

F2' - 74' High Precision Floating Point Runge-Kutta II. Closed Subroutine (auxiliary routine must be supplied by user). This program uses a variant of the Runge-Kutta method known as Kutta's Simpson's rule (see "Numerical Solutions of Differential Equations" by H. Levy and E. A. Baggott, Dover Publications, Inc., 1950).

Consider the set of n simultaneous, first-order, ordinary differential equations:

$$y_i' = f_i\ (y_0;\ y_1;\ \ldots;\ y_{n-1}),\ i = 0,\ 1,\ \ldots,\ n-1$$

and a set $\left\{ y_{i,0} \right\}$ of initial values, where a second subscript, equal to zero, has been used to identify these initial values. Let t represent the independent variable, the initial value being denoted by t_0. The solution at $t = t_0 + h$ is represented symbolically by $\left\{ y_{i,h} \right\}$. The algorism used here is characterized by the following set of equations for $y_{i,h}$, which apply for $i = 0,\ 1,\ \ldots,\ n-1$.

$$y_{i,h} = y_{i,0} + \frac{1}{6} \left\{ \Delta_1 y_{i,0} + 2\Delta_2 y_{i,0} + 2\Delta_3 y_{i,0} + \Delta_4 y_{i,0} \right\}$$

where

$$\Delta_1 y_{i,0} = h\ f_i\ (y_{0,0};\ y_{1,0};\ \ldots;\ y_{n-1,0})$$

$$\Delta_2 y_{i,0} = h\ f_i\ (y_{0,0} + \tfrac{1}{2}\ \Delta_1 y_0;\ y_{1,0} + \tfrac{1}{2}\ \Delta_1 y_{1,0};\ \ldots;$$

$$y_{n-1,0} + \tfrac{1}{2}\ \Delta_1 y_{n-1,0})$$

$$\Delta_3 y_{i,0} = h\, f_i\,(y_{0,0} + \tfrac{1}{2}\Delta_2 y_{0,0};\ y_{1,0} + \tfrac{1}{2}\Delta_2 y_{1,0};\ \ldots;$$

$$y_{n-1,0} + \tfrac{1}{2}\Delta_2 y_{n-1,0})$$

$$\Delta_4 y_{i,0} = h\, f_i\,(y_{0,0} + \Delta_3 y_{0,0};\ y_{1,0} + \Delta_3 y_{i,0};\ \ldots;$$

$$y_{n-1,0} + \Delta_3 y_{n-1,0})$$

In this notation the following convention is to be understood: if the independent variable appears explicitly in the differential equations it is here identified with one of the y_i's, say y_0 (i.e., $t = y_0$). This is a fourth-order approximation, the truncation error being of the order h^5. To put it more precisely, this algorism for $y_{i,h}$ agrees identically with a Taylor series expansion about $y_{i,0}$ up to and including terms in h^4, but it disagrees in higher order terms.

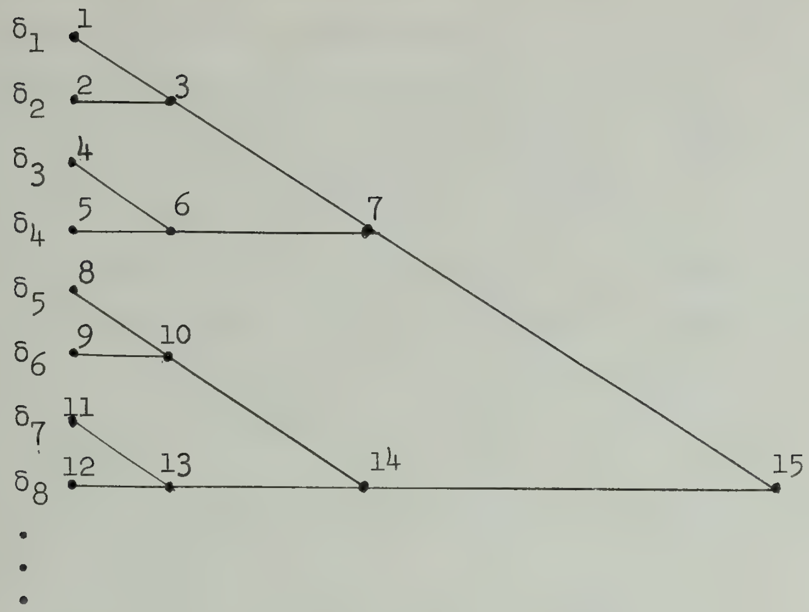
In this program the step by step solution of the set of differential equations proceeds as follows. During the execution of one integration step the four sets of quantities $\left\{h^{-1}\Delta_1\ y_{1,0}\right\}$, $\left\{h^{-1}\Delta_2\ y_{i,0}\right\}$, $\left\{h^{-1}\Delta_3\ y_{i,0}\right\}$, and $\left\{h^{-1}\Delta_4\ y_{i,0}\right\}$ are evaluated by an auxiliary routine which must be written by the user. The Runge-Kutta subroutine makes entry to the auxiliary four times during an integration step to obtain these four quantities. Before the first entry the Runge-Kutta subroutine loads a block of locations called the function block with the values of the variables $y_{0,0}$, $y_{1,0}$, $y_{2,0}$, ..., $y_{n-1,0}$. The auxiliary uses these quantities to evaluate $h^{-1}\Delta_1 y_{0,0}$, $h^{-1}\Delta_1 y_{1,0}$, $h^{-1}\Delta_1 y_{2,0}$, ..., $h^{-1}\Delta_1 y_{n-1,0}$, and then it transfers control back to the Runge-Kutta subroutine. Before the second entry this closed subroutine loads the function block with

$y_{0,0} + \frac{1}{2}\Delta_1 y_{0,0}$, $y_{1,0} + \frac{1}{2}\Delta_1 y_{1,0}$, ..., $y_{n-1,0} + \frac{1}{2}\Delta_1 y_{n-1,0}$; the auxiliary evaluates the quantities $h^{-1}\Delta_2 y_{0,0}$, $h^{-1}\Delta_2 y_{1,0}$, $h^{-1}\Delta_2 y_{2,0}$, ..., $h^{-1}\Delta_2 y_{n-1,0}$, and again transfers control back to the Runge-Kutta subroutine. The next two entries proceed in a corresponding fashion. At the completion of the fourth entry to the auxiliary the Runge-Kutta subroutine evaluates the quantities $\{y_{i,h}\}$ and then the next step begins with the set $\{y_{i,h}\}$ now replacing the set $\{y_{i,0}\}$. After a certain number of steps, N, have been completed, this process stops and control is transferred to the main routine (specifically, to the location loaded into the distributor upon entry to the subroutine); N is specified by the user before entry to the subroutine; see "ENTRY".

All of the arithmetic is performed in floating point. Particular care is taken to keep the roundoff error small. Let us now consider the technique that is used for this. At the completion of the r^{th} step we may write

$$y_{i,rh} = y_{i,0} + \frac{h}{6} \sum_{j=1}^{4r} \alpha_{i,j} (h^{-1}\Delta_{i,j})$$

where the $\Delta_{i,j}$ are the increments to the solution and the $\alpha_{i,j}$ are the multiplying coefficients, 1 or 2, for these increments. For brevity let us now drop the index i and let $\alpha_{ij}\Delta_{ij}$ be represented simply by δ_j. As the δ_j are computed they are accumulated in a binary ladder like that described for library routine E1'. The logic of this accumulation process is illustrated in the picture below.



The quantity δ_1 is computed first, the quantity δ_2 is computed second. These are now combined to form $\delta_1 + \delta_2$, as indicated by the joining of the lines from δ_1 and δ_2. Next δ_3 is obtained, then δ_4 is obtained and these are combined to form $\delta_3 + \delta_4$ and then this sum is combined with $\delta_1 + \delta_2$ to form $\delta_1 + \delta_2 + \delta_3 + \delta_4$. Next δ_5 is obtained, and so forth. The joining of lines in this picture indicates a summation and the number at the point at which the lines join indicates the order in which the operations are performed. The strategy of this process is to try to add numbers together which are approximately of the same order of magnitude, thus minimizing the loss of significant digits which is caused by the right shift executed in aligning the decimal point during the execution of a floating point addition. At the beginning of each integration step the partial sums in the binary ladder are added together and the resultant sum is added to y_0 to form y_{rh} (assuming r steps have been executed). Hence, the current value of the solution is computed anew at the beginning of each step. As soon as δ_j has been computed by the main program it is added into the ladder. Thus, this step in the summing process takes place after every exit from the auxiliary.

The rather elaborate process used for the accumulation of the sums is programmed as efficiently as is possible, with respect to execution time, at the expense of storage space. Each function y_i requires a separate binary ladder. The storage for each ladder and the orders for summing the items in that ladder are located in one band on the drum. When a δ_j is to be added into the ladder, or when the partial sums in the ladder are to be combined at the start of an integration step, this band is transferred to the IAS and the summation takes place within the IAS.

(C. Wilmot)

F3' - 75' Complete Program (auxiliary routine must be supplied by the user). This is a complete program version of a routine based upon the methods described above under F2' - 74'.

(C. Wilmot)

International Business Machines 650 Usage

During the month of August, specifications were presented for 18 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 300'. Numbers followed by T are for theses.

300' Mechanical Engineering. Stresses of a Circular Disk. A study to determine the stresses of a circular disk involves evaluating the following expression,

$$\sigma_y = \sigma_x - (\sigma_p - \sigma_q) \cos \theta,$$

where σ_y is the stress in the y-axis, σ_x is the stress in the x-axis, σ_p is the maximum stress, σ_q is the minimum stress, and θ is the angle between the x-axis and the maximum stress. The International Business Machines 650 will be used to compute these values.

301' State Water Survey. Severe Storm Instability Analysis. In a previous study, Problem No. 227', the area was computed between the actual lapse rate of an upper air sounding and a moist adiabatic lapse rate generated by an instable parcel of air as it rises through the atmosphere. This study will use the same procedures and results to investigate the instability of severe storms.

302' Animal Science. Optimum Combinations of Corn and Soybean Protein. Dosage response patterns will be subjected to regression analyses to determine linear and quadratic effects and dosage for maximum response. The dependent variables will include egg production, egg weight, feed intake, and body weight. The independent variable considered will be initial weight.

303'T Theoretical and Applied Mechanics. Solution of Transcendental Equation. This research problem is a study of the cumulative fatigue damage in SAE 4340 steel. The stress or loading history used to create fatigue failure is expressed as a transcendental equation. It is desired to find the maxima and minima points of this equation. To solve for the first derivative for the desired points, a trial-and-error procedure will be used. It is desired to use the IBM 650 to obtain these solution points.

304' Education. Prediction of Success in Graduate School through Use of Graduate Record Examination. The Graduate Record Examination was given to approximately 1100 incoming graduate students in the fall of 1960-61. The question was asked if this examination would lead to greater precision in the prediction of success in graduate school. This study is to help answer that question. The IBM 650 will be used to calculate multiple correlations to determine the weight the examination should carry in the admission of future graduate students.

305' Political Science. Presidential Election Voting Behavior Study. The research attempts to explain why 360 individuals from the Champaign-Urbana area voted the way they did in the 1960 presidential election. The respondents, part of a representative sample of adult citizens, were interviewed four times during the presidential election period and once in the post-election period. Three times during the course of the campaign the respondents filled out questionnaires in which they rated 25 political and personality concepts on ten scales. Each scale consisted of a pair of polar terms separated by a seven step scale. The ten scales were chosen to represent the three or four principal dimensions of political judgment. The IBM 650 will be used to compute intercorrelations of the ten concepts for the political and personality concepts. The resulting correlation matrices will be factor analyzed to assess the principal dimensions of political judgment.

306'T Agronomy. Dwarf Corn Study. This research problem involves a comparison of homozygous dwarf, homozygous normal, and heterozygous crosses of several corn inbreds. Comparisons will be made in terms of yield, ear weight, and weight per 100 kernels. These characteristics are also affected by the density of the stand. Therefore, it is necessary to adjust the results for differences in stand from plot to plot. The methods of covariance analysis are applicable to this problem and library routine K9' will be used for this purpose.

307' Economics. Convex Programming Technique Applied to Economic Allocation of Electrical Load. To prepare for a term paper in Economics 372, a linear programming routine will be used to illustrate a new minimum cost allocation of a total electrical demand for a large number of electrical generators in an electrical power system.

308' Dairy Science. Multiple Regression Analysis of Large Commercial Dairy Herds. It is desired to reanalyze these data using multiple regression analysis. There are two dependent variables, total income and return on capital investment, and twenty independent variables. These include cost of production variables, prices received, and herd management variables. It is desired to find a good subset of variables to predict the total income and the return on the investment.

309'T Psychology. Correlational Analysis of Concept Formation. The research problem is an analysis of a concept formation task by means of Pearson product-moment correlations. To analyze the data, 10 inter-correlation matrices of 21 variables with a sample size of 32 will be required.

310' Home Economics. Correlates of Nursery School Behavior Patterns with Assessed Maternal Child-Rearing Attitudes and Practices. Behavioral scientists have long held that the child's familial experiences are prime determiners of his personality. This project is of value in helping to supply objective evidence in support of some hypotheses which have been founded on psychoanalytic and other clinical judgments, and often accepted intuitively. This is an attempt to place this assumed intuitive knowledge on a more solidly established scientific foundation. Accurate knowledge concerning the manner and influence of parents on the developing personality and character of their children can be of great theoretical and practical value.

The working hypotheses, as well as some of the general methods used in this study, have grown out of the work of Baldwin at the Fels Research Institute, and Sears in the "Patterns of Child Rearing" study. More particularly, it is related to a recent study by Dr. J. C. Finney. In that study, twenty-one hypotheses of parent-child relationships were tested, using thirty-one families who had applied for help at the Champaign County Mental Health Clinic. It is desired to cross validate the previous results, to explore some new relationships suggested by previous studies, and to discover whether the relationships found in a clinic population also hold true in a normal population group.

311' Provost's Office. Television Research. The purpose of this program is to study ways of employing television for educational purposes. It is hoped also that other variables in the teaching process, such as the place where classes are held, in dormitories, sororities, classrooms can be studies as to their effect. Modes of television presentation and use of visuals are to be studied and their effects determined.

This study includes the investigation of the possibility of using students as leaders of discussion in a particular course. The problem of how these students are to be trained is to be investigated. Specifically, this study concerns itself with the Sociology 104-5 course given on television.

312'T Food Technology. The Development of Corn Carbohydrate Coatings for Control of Shrink and Preservation of Quality of Food Products. The variables involved in this problem are different formulated coatings applied to various food products such as, frankfurters, eggs, green peppers, nuts, etc. Other variables are storage conditions (temperature and relative humidity). An analysis of variance will be used for analysis. The problem is to determine if formulated carbohydrate coatings increase the acceptable storage time over uncoated foods previously mentioned.

313'T Agronomy. Establishment of Legumes with Use of Herbicides. This study involves the use of several herbicides to determine their effects in controlling weed competition in spring seedings of several legume hay and pasture species. A number of experiments have been conducted and will be analyzed using the IBM 650 analyses of variance and single degree of freedom analyses will be used. Legumes have slow development in the seedling stage. In the past, small grain

crops have been used to help control weeds, not injure the legumes, and allow the production of at least two tons of weed-free hay in the seeding year, the high costs of purchasing and applying herbicides may be justified. These studies will help determine the practicality of using herbicides.

314' Electrical Engineering. Cubic Equation by Newton's Method. The problem is a simple Newton Method Solution for the root of a cubic equation. It permits ten iterations but an IBM 704 found the answer within three iterations. The problem is a means of observing how the FORTRANSIT compiler system works on the IBM 650. The program is written in FORTRAN.

315'T Institute of Labor and Industrial Relations. Differential Needs of Research Personnel. Differences will be indicated via the use of "F" ratios, "T" tests, and/or simple analysis of variance among the sub groups.

Overall differences will ultimately be related to job satisfaction as indicated by turnover.

316' Civil Engineering. Soil Grain Size Analysis. A standard computation of soil grain size by Stoke's formula will be made. Functions to be used in formula are entered in four tables. The program initiates the required table look-ups, computes the grain sizes and prints the required data and answers in floating point. The time (t) required for a small soil particle (< .002mm) to settle a known distance (L) is a function of the particle diameter (D), the temp of the fluid medium through which it settles, the viscosity of the fluid (μ), and the specific gravity of the soil particle.

$$D = \phi\ (\text{temp}, t, \mu, \text{S.G.}, L)$$

Stoke's formula gives the diameter as

$$D = \sqrt{\frac{30}{980}\,\frac{\mu}{S_G - 1.0}\,L/t} = K_T\sqrt{L/t}$$

$K_T = \phi'$ (temp., S.G.). K_T has been previously tabulated and is tabled in the program, for

$$16^{\circ}C \leq \text{temp} \leq 35^{\circ}C$$

$$2.50 \leq SG \leq 2.90$$

L is a function of what is called the hydrometer reading.

The hydrometer reading is on data cards and L is read from another table.

The hydrometer reading must be corrected according to the specific gravity of the fluid. This correction factor is also tabled.

The program inputs time, temp, observed hydrometer reading, specific gravity.

Table look-up provides the correction factors and K_T, then D is computed.

The ranges of the various arguments require 600 locations for four different tables.

317' Graduate College. Research Board-Outside Grants. Information on research proposals for which money is requested from outside sources is punched on cards. Included is information as to the department from which the request comes, the sponsor from which the grant is requested, the total requested, the indirect costs requested and the date of the request. If the request has been acted upon, the total granted, the indirect costs granted, and the date of the grant are also punched. The cards will be mechanically sorted by fiscal year. The problem then is simply to sum the requests and grants under various classifications.

The following sums are found:

REQUESTS ACTED UPON

a. The total requested by each of nine general areas.
b. The indirect costs requested by area.
c. The total granted by area.
d. The indirect costs granted by area.
e. The total requested of each nine general classifications of sponsors.
f. The indirect costs requested by sponsor.
g. The total granted by sponsor.
h. The indirect costs granted by sponsor.

REQUESTS NOT ACTED UPON

a. The total requested by area.
b. The indirect costs requested by area.
c. The total requested by sponsor.
d. The indirect costs requested by sponsor.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of August.

TABLE I'

		Hrs:Min	
Scheduled Engineering		31:37	
Unscheduled Engineering		8:03	
Tape Test		:28	
Library Development		56:09	
Agronomy Library	3:06		
DCL Library	52:47		
SSU Library	:16		
Classes		16:01	
Math 295	11:00		
CE 391	5:01		
Instruction		:01	
Demonstration		:23	
Wasted		16:14	
			128:56

Use by Departments

Agronomy		3:49
Animal Science		4:53
Astronomy		:32
Chemistry		7:49
Civil Engineering		5:31
Dairy Science		5:01
Economics		:31
Electrical Engineering		21:22
Food Technology		11:12
Graduate College		13:04
Home Economics		11:08
Instructional TV		2:40
Institute for Research on Exceptional Children		:47
Mechanical Engineering		17:38
Mining and Metallurgical Engineering		5:29
Physical Education		:53
Psychology		2:45
Small Homes Council		1:45
State Water Survey		16:06
Statistical Service Unit		96:48
Agricultural Economics	5:38	
Agricultural Extension	3:34	
Bureau Community Planning	1:11	
Bursar's Office	6:31	
Business Office	8:01	
DHIA	46:31	
Education	3:13	
Finance	:10	
Home Economics	:13	
Marketing	5:49	
Navy Pier	:06	

Physical Education	:29			
Psychology	2:21			
Sociology	8:16			
Student Counseling Service	4:45			
Theoretical and Applied Mechanics		13:18		
			243:01	
				371:57

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for June.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

533 card read punch		10
Failures in reading or punching	4	
Card jam	3	
Reads incorrectly	1	
Bent connector	1	
Edges of cards from punch marked	1	
652 and 727 tape control and tape units		4
Rewinds when should not	1	
Rewinds incorrectly	1	
Tape reel came off	1	
Load rewinds improperly	1	
653 high speed storage, floating point, index registers		4
Lost bits	1	
False light	3	
650		16
Multiple or lost bits	14	
False distributor light	1	
Storage selection	1	
407 accounting machine		5
Prints incorrectly	2	
Not cycling on-line	1	
Fuse blew	1	
Lines printing unevenly	1	
TOTAL		39

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
8/1/61	13:51		1:12	:55	3	(1) 407 not printing ninth digit of word nine. (2) Lost quinary bit in position 3 of program. (3) Lost quinary bit in IAS.
8/2/61	14:27		1:56	:19	2	(1) All units giving trouble in rewinding. (2) False storage unit light.
8/3/61	15:06		:44	:17	1	(1) 533 left marks on edge of output cards.
8/4/61	15:58		:06	:09	5	(1) Lost quinary bit in pos. three of program register. (2) Multiple bits in all registers. (3) 533 card punch jam. (4)-(5) Multiple bits in all registers.
8/7/61	12:24	3:59			0	
8/8/61	23:54			:06	0	
8/9/61	18:11		:05	:12	4	(1) Tape spun off unit 2 while running. (2) Tape unit 2 gave trouble in load rewinding. (3) Card jam in 533 punch. (4) Position 4 of distributor had multiple bits.
8/10/61	23:50			:10	0	
8/11/61	15:58			:07	1	(1) Lost a quinary bit in pos. 3 of program register.
8/14/61	:45	7:50		:06	0	
8/15/61	3:17	12:35			0	
8/16/61	15:55			:04	0	
8/17/61	15:41			:09	1	(1) Trouble reading special character.
8/18/61	15:46			:18	0	
8/21/61	12:10	3:46			2	(1) 407 not cycling on line. (2) Pos. 5 of distributor lost bits three times.
8/22/61	15:19		:08	:09	3	(1) Storage selection error. (2) Bent connector in 533. (3) 533 failed to read or punch due to a blown fuse.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
8/23/61	13:28		2:33		3	(1) 533 would not punch. (2) 533 would not read. (3) Card jam in 533 read.
8/24/61	15:40			:08	2	(1) Lost quinary bit in pos. 1 of distributor. (2) Fuse blew on 407.
8/25/61	10:41			4:43	3	(1) False distributor light. (2) Position 1 of distributor lost quinary bit. (3) Lost quinary bit pos. 1 of distributor.
8/28/61	9:05	3:27	(1:00)*	3:23	2	(1) Printing on 407 uneven. (2) Lost a quinary bit in pos. 1 of distributor.
8/29/61	12:34			3:32	2	(1) Lost a quinary bit in pos. 1 of program register. (2) Position 1 of distributor blank.
8/30/61	12:51		1:19	1:20	2	(1) Read side of 533 not working properly. (2) Seven false storage unit lights.
8/31/61	9:12			:07	3	(1) Tape units 1 and 3 did a high speed rewind when they should not. (2) Eight false storage unit lights. (3) Print wheel 107 dropped a minus sign when using board #2.
						*Repair time spent on 407 but the computer continued to operate off line. This figure is not included in total.
TOTALS	316:03	31:37	8:03	16:14	39	

PART VII

GENERAL LABORATORY INFORMATION

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	9	1	9.5
Visiting Faculty	0	4	1.635
Research Associates	3	0	3.0
Graduate Research Assistants	7	19	15.375
Graduate Teaching Assistants	0	1	.25
Administrative and Clerical	4	2	5.0
Other Nonacademic Personnel	40	13	46.4
Total	63	40	81.16

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbaum, J. E. Robertson and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - CIRCUIT RESEARCH PROGRAM
PART III - DATA REDUCTION METHODS
PART IV - MATHEMATICAL METHODS
PART V - ILLIAC USE AND OPERATION
PART VI - IBM 650 USE AND OPERATION
PART VII - GENERAL LABORATORY INFORMATION

September, 1961

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Construction Progress

Table I summarizes the progress during the month toward completion of the computer. Entries in Table I indicate the number of transistors which have completely passed through the phase of design or construction indicated by the column heading. Within one rectangle of Table I, the three figures from top to bottom indicate completions, respectively, at the beginning of the month, during the month, and at the end of the month. The transistor counts are intended to reflect the amount of work directly applicable toward completion of the computer, rather than total effort expended. For example, if the wiring of a chassis has to be modified, it is removed from the "completed" list, and indicated as having been wired again during the month in which the modification is made.

Completion of systems design indicates that the general strategy of design has been worked out in some detail. For a control, for example, a mnemonic order code would be fixed on completion of systems design, although the numerical equivalents for each order would be unknown. Logical design completion would be indicated by a logical diagram in which circuit restrictions on fanout and cascading are observed, but physical distances and consequent cable driver circuits are not included.

Physical placement is completed when chassis boundaries are fixed, and cable driving circuits included in the logical diagram. In block layout, the function of each transistor on a chassis is indicated by circuit block symbols. Information sufficient for drafting, frame wiring, component layout, and power supply requirements is available on completion of block layout.

Component layout requires as many as 14 drawings for each chassis, showing successive phases of wiring of the chassis.

Table I

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Drafting	Subsystem Test	Systems Test
Repetitive M.A.U. 5380	5380	5380	5380	5380	5380	5380	5380	5380	5380	5380	
Core Storage Unit (4096 words) 3883	3883	3883	3883	3883	3883	3883	3883	1689 2134 3823	2150 2150	0 0	
Delayed Control EAU, End Connections 11200	11200	11200	11200	1064 3342 4406	1064 966 2030	98 596 694	98 596 694	98 596 694	789 72 861		
Flow Gating (Buffer Storage) 3987	3987	3987	3987	3663 324 3987	3663 169 3832	3404 168 3572	3404 168 3572	3404 168 3572	3842 3842		
Advanced Control 7000	7000	2100	0								
Drum Storage Unit 4000	4000	0	0								
Interplay Control 3000	3000	0	0								
Paper Tape Input-Output 641	641	641	641	0 641 641	0 508 508	0					
Test Controls	1434	1201 233 1434	1201 233 1434	438 373 811	438 373 811	438	438	438	438	438	
TOTALS	 40525	28392 233 28625	26292 233 26525	14428 4680 19108	14428 2016 16444	13203 764 13967	13203 764 13967	11009 2898 13907	12599 72 12671	5818 0 5818	0 0 0

The static test involves application of D.C. power to the chassis before transistors are plugged into sockets. Voltage measurements at all nodes indicate faulty components, wiring errors, etc., not caught during visual inspections.

A subsystems test is a dynamic test of several thousand transistors using a relatively simple fixed program usually generated by a small special purpose control to be discarded later. Systems tests can occur when sufficient equipment is assembled to run programs read from punched tape.

2. Subsystems Tests of the Repetitive Chassis of the Main Arithmetic Unit

Continuous operation of the repetitive chassis of the MAU was attempted during the period September 1-18. The mean time to failure during this interval was 44.6 hours, with a longest run of 145.5 hours. Of the eight interruptions, five were due to component failures, two were unknown, and one was due to a failure of A.C. power to the building.

During the week of September 18, 515 transistors in one four-bit vertical section were replaced by recently purchased Texas Instruments type S-166 transistors. Marginal checks, in the form of a variation in each voltage by 4% both above and below the nominal value, were performed. Each of 4 voltages in each of nine regulating modules, for a total of 36 tests, were performed in this way. It was found that changing the -50 to -48 caused one F-element in each of two bays to fail to hold a 1 during gating. For further details, see the description of the same trouble encountered earlier with the slow circuits. (Section 10.2, Part I, Technical Progress Report for June, 1961)

Table II summarizes the component failures detected in the repetitive MAU chassis since D.C. and dynamic tests were initiated early in May.

Table II

Component Failures in Repetitive MAU Chassis

Type of Fault	Initial Chassis Checks (Note 2)	Hours of Operation of Subsystems Test								Totals
		0-100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	
Open Resistors	25	18		1		1				45
0.1 µf Condensers	22	8	3	1	1			1	1	37
200 µf Condensers	Note 1	9			2					11
18 µf Condensers	Note 1								1	1
Diodes	24									24
Transistors	8	3								11
Stabistors		1								1
Indicator Bulbs	21	5								26
TOTALS	100	44	3	2	3	1	0	1	2	156

Note 1: These condensers are wired on the main frame, and were not in use during initial chassis checks.

Note 2: For more details, see the Technical Progress Report for May, 1961, Part I, Section 2.

3. Circuit Design

A delay line driver, designed in August, has been built and tested using delay elements from Ad-Yu and Columbia. The results are promising and a final report awaits the arrival of the remaining lines that have been ordered. Additional lines of about 1.0 and 0.7 μsec., the latter variable, are required for the drum. These are not ordered as yet.

A final design for row, column and write drivers has been completed for the drum. Tolerance analysis and complete testing of assembled components remains. A report will be written on the details of these designs and the intermediate and final test results which support them.

Mr. E. E. Freeman of Chicago Miniature Lamp Works has presented two sets of drawings for the nonlinear, resistor-lamps referred to in August. He is in the process of making samples of one desirable inexpensive version. A description of the proposed application of such lamps has been sent to him in exchange for the devices.

(K. C. Smith)

4. Interplay

Suitable circuits have been designed for use in the interplay buffer registers. These use two transistors per bit of buffer storage. Driver circuits for controlling the buffer registers are under development. A ring counter has been designed for counting the characters in a word to distribute character reading and writing to the various parts of a two-word buffer register. These circuits all use the standard slow-circuit transistors and the NPN high-power 2N696 as a driver in saturating circuits to achieve a substantial reduction in cost.

The interplay buffer control logical design has been done, using standard slow circuits. The total cost of an interplay channel is about 550 transistors, of which 265 are used in the buffer storage, and the remainder in control and drivers. The circuit and logical design allows these channel units to be remote from the computer, and maximum distance being about 100 ft. Flow-charting and preliminary logical design of the central interplay control has been done. Including several selectors shared with advanced control, this section will probably total about 2000 transistors, mostly standard fast circuits.

(C. S. Wallace)

5. Magnetic Drum Memory

The scheme used for setting up a block transfer to or from the Magnetic Drum Memory was extensively revised. The object was to allow more time between successive block transfers for the Transfer Interruption Routine (TIR) to set up the next transfer without wasting a sector time (1996 μsec). The February, 1961 scheme was completely sequential in that all the Advanced Control and Interplay operations needed to set up a transfer had to be completed before the Drum actions began. The September, 1961 scheme allows some actions to occur in parallel. Specifically, as soon as A.C. has generated a drum order (consisting of the drum block address and a read or write bit) then the drum band selection process begins and continues while A.C. is setting up the Core Memory end of the transfer. After both of these actions are completed, and after some other timing requirements are satisfied, the data transfer begins. The sector clock track waveforms were also changed. The result of these changes is that after the end of one block TIR can wait up to 60 μsec before supplying the next drum block address and it can wait about 125 μsec before generating the core memory starting address and setting the Drum Go signal. A file report describing these changes is in preparation.

(H. C. Brearley)

A large part of the Sector Selection and Timing logic (Drawing D-1300) was redesigned to incorporate the changes mentioned above. A parity circuit which writes and reads character parity on the drum and sends and receives word parity from Interplay was designed (D-1304). A circuit to synchronize character transfers between Interplay and Drum was developed on the assumption that peak detection during reading will be possible (C-1302). A one shot multivibrator delay circuit for use in the coincidence circuit was designed, and is to be tested.

A manuscript on the peak detection scheme and a manuscript on the sector timing, bit timing, interplay synchronization and parity circuits are in preparation.

(M. Falleni)

The experiments so far performed on the experimental magnetic disk were published (File No. 399, September 13, 1961 by C. N. Liu and P. V. S. Rao).

Based on these experiments and on the purchase specifications for the magnetic drums (File No. 332, February 21, 1961) a set of proposed experiments for the drums was enumerated (File No. 404). The object of these experiments is (1) to test the drums to the purchase specifications, (2) to repeat some of the experiments done on the experimental magnetic disk, and (3) to perform those experiments which could not be performed on the magnetic disk because of its nature or for other reasons.

Difficulty was experienced during the magnetic disk experiments because of the absence of a convenient means of generating arbitrary write current bit patterns in synchronization with a clock pulse. Therefore, a cyclic bit pattern generator, a simplified form of which is shown in Figure 1, has been built and is ready for testing. It can generate any arbitrary sequence of 1's and 0's, 16 bits long, by setting 16 switches. A file number on this generator will be prepared, giving more details.

Possible replacements for the 2N397 row and column drivers were investigated using the circuit of Figure 2. Switching behavior and saturation voltages were investigated for i_c = 50 to 200 ma, i_b = 0.6 to 16 ma. Transistor types 2N397, 2N1997, 2N1998, 2N2000, 2N2001 were tested; the last two types were deemed most satisfactory.

(P. V. S. Rao)

A number of drum write circuits were tested. Output rise and fall times for a possible circuit, showing the operation times of the circuit for several different transistor types, were presented in a memorandum dated September 14, 1961. One of the better circuits used a 2N1309 switching amplifier, a 2N711 emitter follower and a 2N834 output stage.

A possible "row select" circuit and a possible "column select" circuit for drum head selection were similarly tested, and results were presented in memorandum of September 20 and 21. Circuit operation times of less than one microsecond were found in each case.

If time permits, a file report will be written summarizing the results of these tests.

(R. L. Cummins, K. C. Smith)

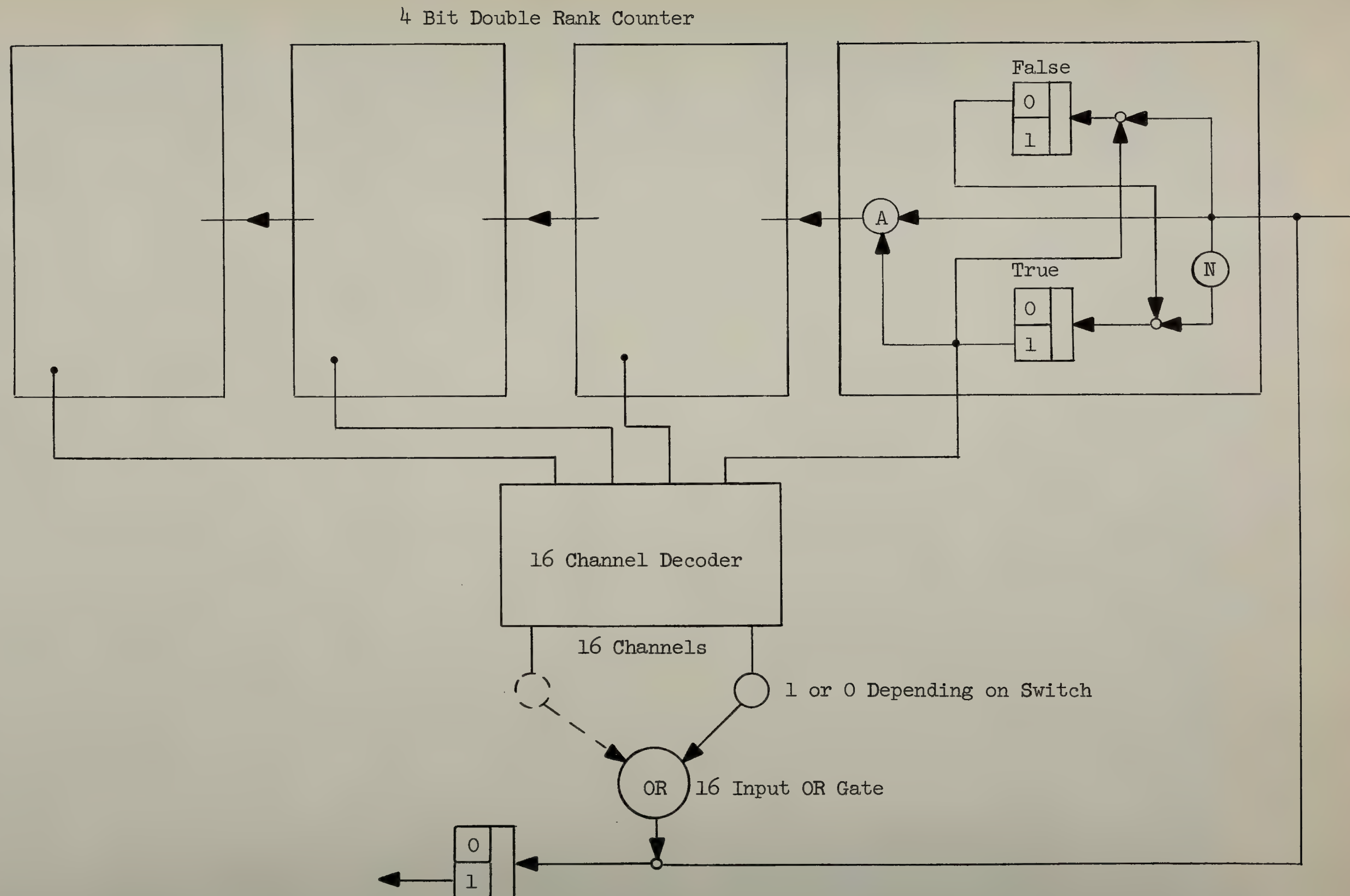

Figure 1

Cyclic Bit Pattern Generator

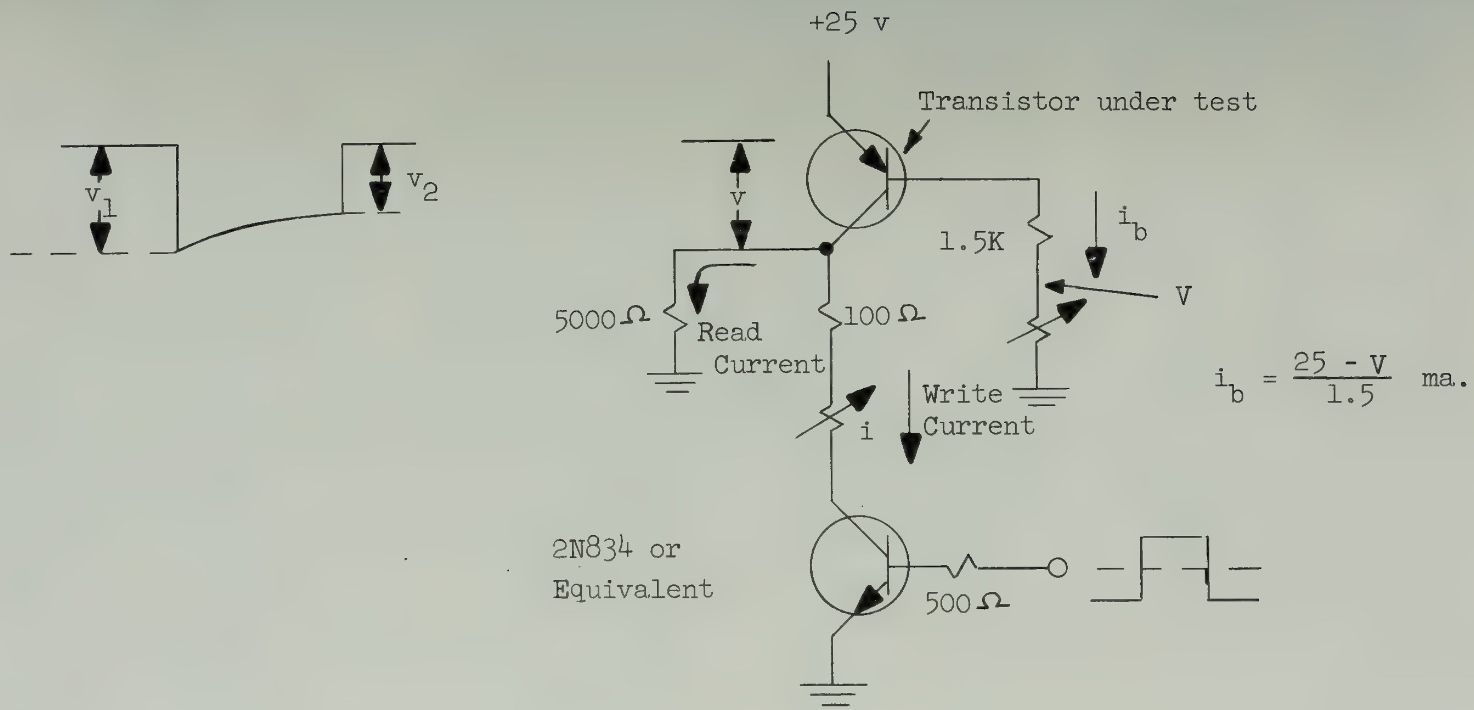

Figure 2

Test Circuit for Saturation Behavior of PNP Transistors

(to be used as row and column selectors)

Further experiments were performed on the differential read amplifier described in the July report. The circuit operated satisfactorily when large pulses of opposite polarity were applied to the two inputs, simulating the write voltages.

Tests were begun on a final write amplifier with gate. The inputs are a Write 1 or 0 bit and a Write or Read bit. The outputs are 100 ma currents to the heads. The complete circuit for driving one head uses only 9 transistors.

(H. Yazaki)

PART II
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

H. Guckel continued his work on a tunnel-diode system. Experiments showed that it is practically very hard to stabilize supply voltages when kmc signals are involved and it is now planned to use constant current supplies: in order to do this parallel combinations of tunnel diodes and resistors must be used (see below).

J. Hill obtained the first results in his study of failsafe circuits. In particular the design of a NOT circuit is well along the way. Some ideas are explained below. A fuller report will be issued when this circuit has been tested in practice.

T. Burnside continued his probability theory approach to circuit design. Since fundamental questions of a mathematical nature need clarification, no report will be given at this stage.

S. Ribeiro reverified the supersaturation phenomenon and also worked on a possible theoretical explanation. He supposes in essence that for low collector voltages and a high injection level the Fermi-level in the base region is modulated by the current in the collector. This implies a strong reaction of the collector current on the emission at the emitter base junctions. An outline of his calculations is given below.

2. Tunnel-Diode Work

Tunnel-diode work was concentrated on the development of a symmetrical, bilateral NOT circuit. Experiments performed with coaxial transformers fall into two categories:

1. AC-coupled 1:1 inverter (voltage)
2. DC-coupled 1:1 inverter (current)

Some success was achieved with type 1 circuitry. However, time constants involved in the coupler are critical, resulting in unreliable operation as far as the memory element is concerned. The 1:1 coupling ratio is not maintained very well since shield and center conductor currents are not quite equal. This is mainly due to end effects and is partically eliminated by using longer inverting sections and more beads. It is also believed that the pass band of the transformer does not include all the frequencies contained in the pulse generated by an astable stage. This cannot be investigated with the sampling scope, since the pulse is only ~200 psec long. However, measurements with the diagraph support this opinion.

The results of type 2 circuits are not completed but do not look promising. It is now believed that the voltage supply in a system is not necessary. This may be seen by examining Figure 1.

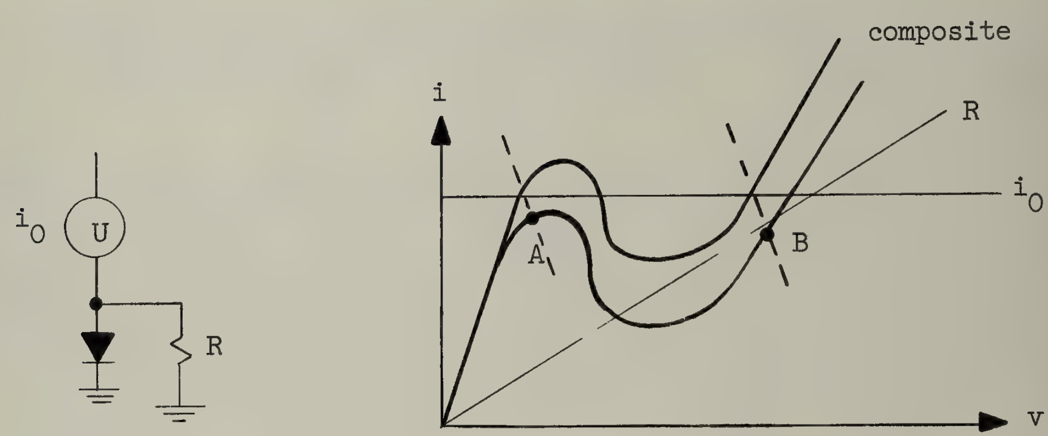

Figure 1

Composite Load with Current Source

Visibly the properly loaded stage has the same characteristics as the diode driven from a voltage source as shown in Figure 2.

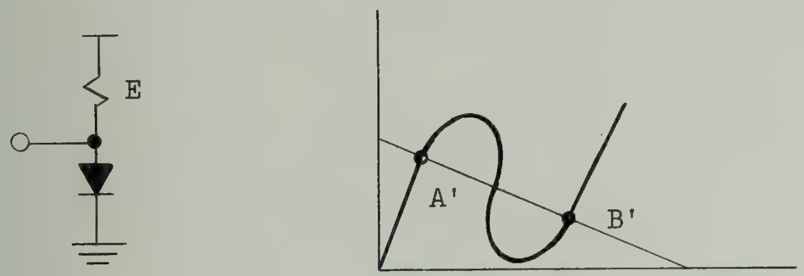

Figure 2

Tunnel Diode with Voltage Source

Some attempts were made to measure the tunnel diode characteristics by a setup according to Figure 3.

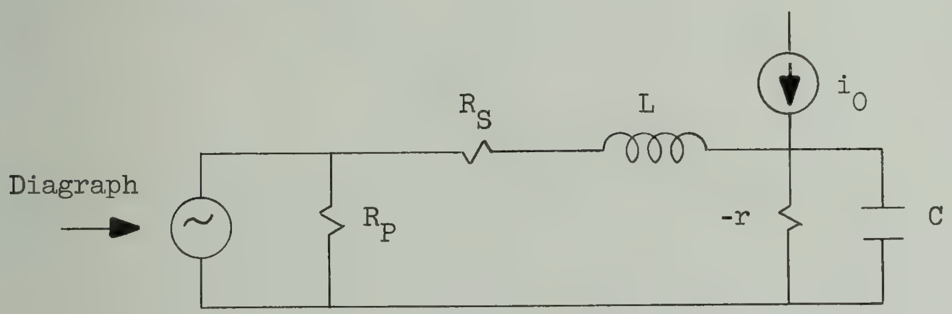

Figure 3

Setup to Measure Tunnel Diode Characteristics

For stability it is required that:

$$\frac{R_P\ (R_S-r)}{R_S+R_P-r} > 0 \qquad \text{with } R_S < r$$

$$\therefore \qquad R_S + R_P < r$$

R_P was lowered to $1\,\Omega$ indicating that the diode characteristic drops very steeply, i.e. looks like the curve in Figure 4(a) rather than in Figure 4(b).

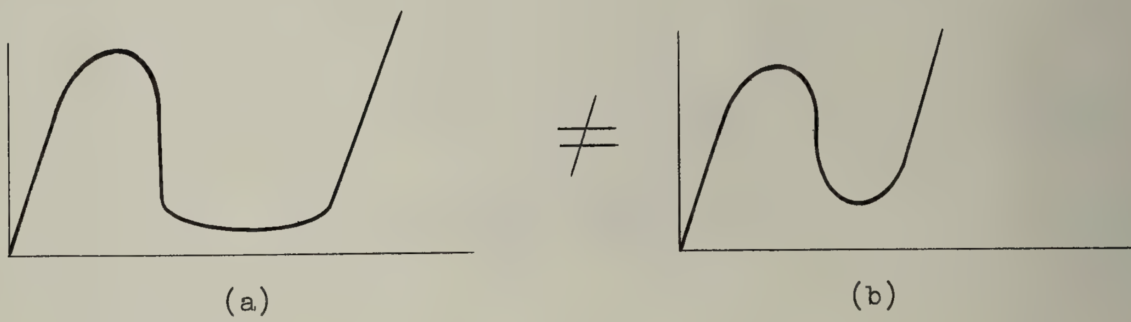

Figure 4
Tunnel Diode Characteristics

However, it is impossible to obtain reliable data in this fashion since the difference between $1000\,\Omega$ and $100\,\Omega$ shunted by $1\,\Omega$ is not large enough. The work will be continued in a piece-wise fashion by using several values of R_P.

3. <u>Failsafe Circuits</u>

Research has been started in failsafe circuit design. The main goal is the design of transistor circuits with the property that any one of the semiconductor elements in a logical circuit may undergo a failure of either the short-circuit or the open type without effect on the overall circuit performance. An example circuit is the series parallel diode configuration illustrated in Figure 5. The overall circuit performs the same function as a single diode, but if any diode of the quadruple shorts out or opens, the circuit performs without failure. Whether or not the bridging connection is made depends on the relative susceptibility of the diode elements to shorts and opens. With slight modification, this basic series-parallel circuit can be extended to construct a failsafe transistor as illustrated in Figure 6. The circuit with current

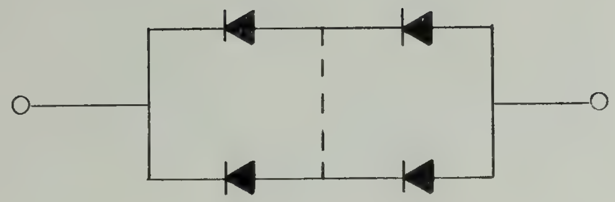

Figure 5

Failsafe Diode Combination

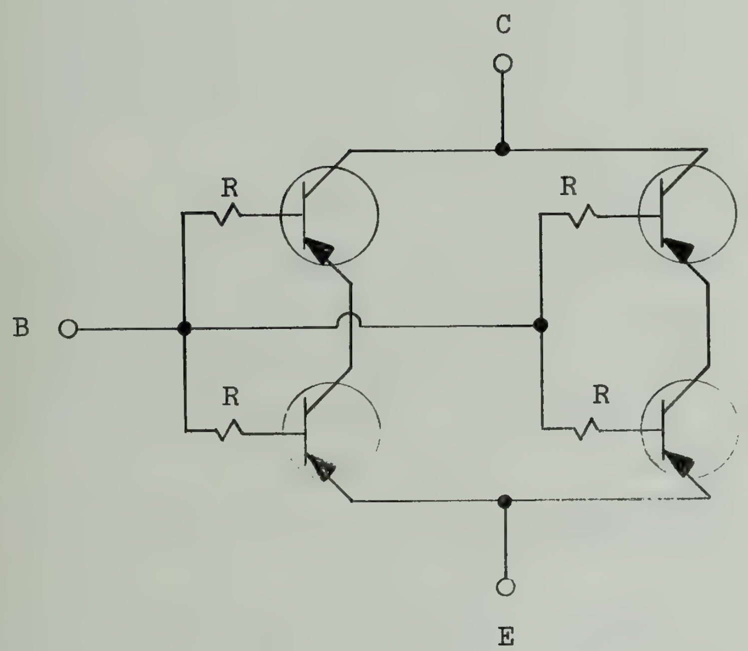

Figure 6

Failsafe Transistor Combination

limiting resistors R is not made inoperative by any single transistor failure (all combinations of shorts or opens in a transistor).

Presently, the main goals are 1) to reduce the number of transistors required for this redundancy from four to three or possibly two. It appears that the lower limit for a single circuit may be a multiplication of components by three. However, there is hope that in more complex circuits the required degree of failsafeness can be achieved with only a doubling of circuit elements. It is hoped 2) that all standard circuits (AND, OR, NOT, FF, etc.) can be designed using configuration as shown in Figures 5 and 6 without assuming unduly close tolerances for resistors and voltage supplies.

4. Supersaturating Transistors

Introduction

It has been observed that, under conditions of high emitter current and low collector voltages (order of 50 mils and 0.5 volts respectively) an alternating current (500 cps) fed into the collector controls a large current in the emitter circuit.

Theoretical Hypothesis

It is believed that the alternating current fed from the collector into the base modulates the minority carrier density in the base, which in its turn, modulates the Fermi-level in the base. This is equivalent to a variable voltage source between the base and emitter. Hence a variation of current is produced in the emitter circuit. In summary: a voltage source at the E-B junction is controlled by the minority carrier densities modulated by the collector current.

As a refinement, one has to take into account the voltage drops due to base and emitter resistance (and, a simple generalization, any loads in series with them).

Analysis

To obtain the value of alternate minority carrier density as a function of current the base diffusion equation was solved:

$$\frac{dP}{dt} = - \frac{P}{\tau} + g; \; g = \text{sources and sinks} \qquad (1)$$

(Assuming no fields and uniform carrier densities.)

Setting $g = \frac{I_E + I_C}{q \delta S}$ and isolating the alternate (small signal) components of currents and carrier density,

$$P_{\sim} = \frac{\tau i_{\sim}}{q \delta S} \cdot \frac{1}{1 + j\omega\tau} \qquad (2)$$

with:

τ = minority carrier lifetime in the base.

δ = base width.

S = base area.

q = electron charge.

From the equation $P = N_v e^{-\frac{E_F - E_V}{kT}}$ (3)

(whose restrictions we suppose are satisfied) we get, for the alternating component of the Fermi-level as a function of carrier density:

$$E_{F_{\sim}} = - \frac{kT}{P_0} P_{\sim} \qquad (4)$$

where P_0 is the steady state hole density in the absence of a signal.

Suppose then that the voltage across the E-B junction will be

$$v_{E_{\sim}} = - \frac{\lambda E_F}{q} \qquad (5)$$

where λ is a factor to take into account the emitter Fermi-level modulation, and is given by:

$$\lambda = 1 + \frac{N_{\sim} P_0}{P_{\sim} N_0} \qquad (6)$$

with $N_{\sim}$ and N_0 measured at the emitter side of the junction.

Finally, the relation between emitter current and voltage across the E-B junction is taken from the well known diode equation:

$$i_E = i_{E\,sat}\; e^{\frac{q\,v_{EB}}{kT}} - 1 \tag{7}$$

We find, for the small signal components:

$$i_{E\sim} = \frac{q\;I_{EO}}{kT}\;v_{E\sim} = \frac{v_E}{\rho}\;;\;\rho = \frac{kT}{q\;I_{EO}} \tag{8}$$

with I_E = biasing emitter current; ρ = dynamic E-B junction resistance.

Results

From equations (2), (4), (5) and (8) we get the first approximation:

$$G_I = \frac{I_{E\sim}}{I_{C\sim}} = \frac{1}{(\eta\rho - 1) + j\omega\tau\eta\rho} \tag{9}$$

where η is a constant given by:

$$\eta = \rho \cdot \frac{Q}{\lambda\;I_{EO}\,\tau} = \frac{P_O\;q^2\,\delta\,S}{\lambda\,\tau \cdot kT} \tag{10}$$

with $Q = P_O\;q\,\delta\,S$ = base minority carrier charge, and ρ as defined in equation (8).

Consideration of r_B' and r_E' ($r_E' = r_E - \rho$) the total base resistance and emitter resistances (except EB junction resistance) with equation (11) below instead of (5):

$$v_{E\sim} = - \frac{\lambda\, E_F}{q} - i_{E\sim}(r'_B + r'_E) - i_{C\sim} r'_B \qquad (11)$$

furnishes:

$$G_I = \frac{I_{E\sim}}{I_{C\sim}} = \frac{(1 - \eta r'_B) - j\omega\tau\eta r'_B}{[\eta(\rho + r'_E + r'_B) - 1] + j\omega\tau\eta(\rho + r'_E + r'_B)} \qquad (12)$$

with η, ρ as defined above.

Experiments will be made to check these results.

PART III

DATA REDUCTION METHODS

(Supported in part under Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

AUTOMATIC REDUCTION OF DATA FROM BUBBLE CHAMBER PHOTOGRAPHS

A large part of this month was spent preparing a technical progress report covering the work done on this program during the past six months. Several extensive reports covering various aspects of the work were written:

File No. 380 Studies on the Automatic Scanning and Measuring of Bubble Chamber Negatives V: A Class of Optimally Efficient Encodings of Bubble Chamber Negatives, by B. H. McCormick, September 1, 1961

File No. 400 Specifications for Two Precision Electrically Advanced 35 Millimeter Recording Cameras, by B. H. McCormick, September 1, 1961

File No. 401 Progress Report on Digitally Addressed Cathode Ray Tube System, by B. H. McCormick, September 1, 1961

File No. 403 Tentative Logical Realization of a Pattern Recognition Computer, by James Divilbiss and B. H. McCormick, September 1, 1961

A report covering certain aspects of the original scanning and tracking programs is also available:

File No. 379 Studies on the Automatic Scanning and Measuring of Bubble Chamber Negatives IV: Track Association Memory (TAM), by B. H. McCormick, S. J. Penny, and J. N. Snyder

A major task during this month has been familiarizing the new staff members who will be working on this program with what has been accomplished to date and with the features within the program which will be the subject of future investigations.

(W. Carskadon, B. Mayoh, B. McCormick, R. Narasimhan, S. Narkinsky, M. Shirazi, J. Snyder and J. Stein)

PART IV

MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research Under Contract Nonr 1834(27).

Monte Carlo Methods in Quantum Statistics

During this month work with the program to calculate the quantum mechanical partition function was resumed after having been suspended for the summer. The calculations performed this month were particularly successful for it turned out to be possible to calculate the partition function to an accuracy of about 5 per cent under rather extreme conditions. An outline of this calculation is indicated below.

Although the program is designed to calculate the partition function for a two-dimensional system consisting of a pair of identical interacting particles enclosed in a "box", in this calculation the interaction was made equal to zero. In this case an exact determination of the partition function by straightforward methods is trivial and then one has a convenient check on the Monte Carlo calculation. The interaction between the particles is zero in the sense that the interaction potential is zero and no symmetry condition is put on the total wave function of the system. Under these conditions the partition function is given simply by

$$Q\ (\text{exact}) = \left[\sum_{k=1}^{\infty} e^{-\frac{\beta h^2}{8mL^2} k^2} \right]^4$$

where $\beta = \frac{1}{kT}$, L is the edge length of the box, and m is the mass of one of the particles. In the classical limit the summation can be replaced by an integration and one has the familiar result

$$Q\ (\text{exact}) \xrightarrow[\text{limit}]{\text{classical}} \left[\frac{2\pi m L^2}{\beta h^2} \right]^2$$

The Monte Carlo computation starts with the formulation of the partition function in terms of a conditional Wiener integral (see Gel'fand and Yaglom, Journal of Mathematical Physics, page 48, (1960) in particular

$$Q = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \left\{ \int_{C_{\beta;0}}\int_{C_{\beta;0}} \exp\left\{ - \int_0^{\beta} V\left[\sqrt{\frac{2}{m}}\,(X_1 + x_1(\tau),\ X_2 + x_2(\tau))\right] \right. \right.$$

$$\left. \left. \cdot\, d\tau \right\} d_w(\beta,0)\, x_1\, d_w(\beta,0)\, x_2 \right\} dX_1\, dX_2$$

The third and fourth integrals (counting from the left) are conditional Wiener integrals; the remainder are the usual Riemann integrals. The function $V[\ \ ]$ is the potential function for the system. Although it hardly looks like it, this expression for the system is completely equivalent to Q (exact) stated above. The integrations indicated here are performed by the Monte Carlo technique described in File No. 361 (February 1961) "Studies in the Numerical Evaluation of Functional Integrals" by L. D. Fosdick. Following the formalism of this technique, it is possible to express Q (Monte Carlo) in the form

$$Q\ (\text{Monte Carlo}) = \left(\frac{2\pi m L^2}{\beta h^2}\right)^2 \left(\frac{F}{R}\right)$$

We note that this is the product of two terms, the first being simply the classical limit. The second term can be regarded as the quantum correction factor. The program computes the factor $\frac{F}{R}$, and thus we can compare $\frac{F}{R}$ (Monte Carlo) with $\frac{F}{R}$ (exact) $= \left(\sum_{k=1}^{\infty} e^{-\frac{\beta h^2}{8mL^2} k^2}\right)^4 \Big/ \left(\frac{2\pi m L^2}{\beta h^2}\right)^2$

A convenient way to describe the "distance" of the system from the classical limit is through the ratio λ/L where λ is the mean de Broglie wave length given by

$$\lambda = \hbar \cdot \sqrt{\frac{\beta}{m}}\ .$$

The classical limit is approached when $\frac{\lambda}{L}$ becomes small; notice that

$$Q\ (\text{exact}) = \left(\sum_{k=1}^{\infty} e^{-\frac{\lambda^2}{8L^2} k^2}\right)^4$$

The Monte Carlo computation has been made for the case $\frac{\lambda}{L} = \frac{1}{2}$ and $\frac{\lambda}{L} = \frac{1}{4}$. It will be recalled (File No. 361) that the functions over which the Wiener integration is performed are sine series of the form

$$x_i(\tau) = \sqrt{2}\sum_{j=1}^{n} \xi_{ji} \frac{\sin j\pi t}{j\pi} .$$

It is only in the limit $n \to \infty$ that the Monte Carlo scheme will converge to the exact result as the number of Monte Carlo samples is increased. (A Monte Carlo sample is characterized by one set of values for X_1, X_2, ξ_{11}, $\ldots \xi_{n1}$, ξ_{12}, $\ldots \xi_{n2}$.) The Monte Carlo computation was run for n = 10, 20, 30. Results are summarized below:

$\frac{\lambda}{L} = \frac{1}{2}$, $\frac{F}{R}$ (exact) = 0.655

$\frac{F}{R}$ (Monte Carlo) tabulated below as function of n and N where N = sample size.

n \ N	100	200	300	400	500
10	.690	.720	.757	.772	.774
20	.690	.735	.733	.725	.736
30	.710	.710	.723	-	-

(Note: The results for increasing sample size are cumulative, hence the results for N = 200 were obtained by adding one more set of 100 samples to the first sample of 100, etc.)

$\frac{\lambda}{L} = \frac{1}{4}$, $\frac{F}{R}$ (exact) = 0.812

$\frac{F}{R}$ (Monte Carlo) tabulated as a function of n and N

n \ N	100	200	300	400	500
10	0.820	0.850	0.880	0.892	0.888
20	0.830	0.855	0.860	0.852	0.850
30	0.860	0.850	0.853	-	-

The computation time for the sample size of 300 with n=30 was about two hours.

Work on this problem is continuing.

(L. D. Fosdick)

PART V

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of September, six new routines were added to the Illiac Library.

F 7 - 312 Integration of Ordinary Differential Equations with Automatic Selection of Elementary Interval (DOI or SADOI). In order to use this routine the system of ordinary differential equations to be integrated must be cast into the form

$$\frac{dy_i}{dx} = f_i\ (x, y_1, y_2, \text{--}\ y_n); \quad i = 1, 2 \text{ -- } n$$

with x and y_i real numbers in machine range and f_i real numbers such that $2^{-m}f_i$ are in machine range. Thus, equations of higher than first order must be reformulated by introducing auxiliary dependent variables obeying first order equations; and the variables of the original scientific problem will in general have to be suitably scaled to make the problem conform to the above.

A detailed description of the method used in this routine is to be published in "Mathematics of Computation", Journal of the Division of Mathematics, National Academy of Sciences - National Research Council, Washington, D. C., about October, 1961.

The method works with polynomials of 5th degree approximating to each of the y_i, and these polynomials are specified by their 0th to 5th derivatives in order to facilitate changes of interval. (Actually the derivatives beyond the first are multiplied by 2^{-m} and by a power of the current elementary interval h and divided by a factorial, as indicated in the data bank description, in order to keep them in machine range and to facilitate the arithmetic).

Equations with discontinuous derivatives are integrable by this method with accuracy comparable with the accuracy for the case of continuous derivatives provided only that the jumps in the derivatives are finite and are scaled properly.

The elementary step from x to $(x + h)$ consists of applying the working equations:

$$y_i(x + h) = y_i(x)$$

$$+ 2^m h \left(2^{-m} f_i(x) + a_i(x) + b_i(x) + c_i(x) + d_i(x) + \frac{95}{288}\left[2^{-m} f_i(x+h) - 2^{-m} f_i^{\,p}\right]\right)$$

$$2^{-m} f_i^{\,p} = 2^{-m} f_i(x) + 2a_i(x) + 3b_i(x) + 4c_i(x) + 5d_i(x)$$

$$a_i(x + h) = a_i(x) + 3b_i(x) + 6c_i(x) + 10d_i(x) + \frac{25}{24}\left[2^{-m} f_i(x+h) - 2^{-m} f_i^{\,p}\right]$$

$$b_i(x + h) = b_i(x) + 4c_i(x) + 10d_i(x) + \frac{35}{72}\left[\quad '' \quad\right]$$

$$c_i(x + h) = c_i(x) + 5d_i(x) + \frac{5}{48}\left[\quad '' \quad\right]$$

$$d_i(x + h) = d_i(x) + \frac{1}{120}\left[\quad '' \quad\right]$$

Here the quantities evaluated at x are known from the previous elementary step (except in the very first step, in which case the "initial entry" must be used and an automatic starting procedure is invoked; see below); and the quantities at $(x + h)$ are to be found. The coefficients 95/228, 25/24, 35/72, 5/48, 1/120 are specially chosen to maximize the stability of the method, to optimize the process of integration across finite discontinuities of the derivatives, and to make the truncation error $O(h^7)$ rather than $O(h^6)$ as it would be for arbitrary coefficients. The truncation error in y_i per elementary step is

$$E_t = + \frac{h^7}{70} \frac{d^7 y_i}{dx^7} + O(h^8)$$

provided the seventh derivative exists.

The solution of the working equations proceeds in three stages. Stage 1 consists of "predicting" all six quantities y_i ... d_i at $x + h$, i. e., applying the working equations without the $\left[\quad \right]$ terms, using as tentative value of h the value which was accepted in the last previous step, or twice that value if the conditions for doubling h were fulfilled. Stage 2 consists of solving the complete first working equation, which is an implicit equation since the $f_i(x + h)$ depend on the $y_i(x + h)$ in virtue of the differential equations. The equation is solved iteratively by inserting the "predicted" y_i on the right, appealing to the auxiliary subroutine for $f_i(x + h)$, thus producing first improved $y_i(x + h)$, appealing again to the auxiliary subroutine and thus finally getting second improved $y_i(x + h)$. The iterative procedure is always terminated after just these two iterations, the second improved $y_i(x + h)$ and $f_i(x + h)$ being accepted as adequate approximations.

At completion of stage 2 two tests are made to determine whether h is sufficiently small. One test determines whether or not the iterative solution of the implicit equation was sufficiently convergent, and this comes to whether or not

$$\frac{95}{288} \left| h \frac{\partial f_i}{\partial y_j} \right| \leq 1/8$$

because the left side of this inequality is the convergence factor. The second test determines whether the truncation error is small enough to be consistent with the accuracy parameter e, and this comes to whether

$$|f_i(x + h) - f_i^{\,p}| \leq (3.03)\ 2^{-e}/|h|$$

If either of these tests is violated, we discard the computations of stages 1 and 2, halve h and enter upon

stage 1 again. If both tests are satisfied we ascertain whether they are "oversatisfied", i. e., whether a doubled h would likely satisfy them, and if so note this fact for future reference; then proceed to stage 3, which consists of "correcting" a_i, b_i, c_i, d_i by adding the [ ] terms.

The above discussion indicates the conditions for automatic reduction of interval. If the tests are not satisfied even after the interval has been reduced to 2^{-39} the FF stop is invoked. The conditions for increasing the interval, on the other hand, are as follows: If before entering stage 1 we have $|h| < 2^{-\ell_o}$ and both tests were previously "oversatisfied" and the digits of $(x-x_o)$ are such that doubling h will not cause the next point $x = x_o +$ (integer) $2^{-\ell_o}$ to be missed, then h is doubled before stage 1 is entered; but after a reversal of sense of integration h may not be doubled until 4 elementary steps have elapsed. The last condition is necessary to discourage occasional erratic interval behavior after reversal.

Automatic starting is a special procedure automatically invoked before the first step away from the initial value x_o, when neither the correct h nor the quantities $a_i \ldots d_i$ are known. This feature relieves the user of the task of supplying special starting information and requires him to supply only the logically essential initial values of the y_i.

In the automatic starting mode the computer clears the $a_i \ldots d_i$ locations and then repeatedly integrates four steps forward and four steps back to x_o. Because of the high degree of stability of the method the quantities $a_i \ldots d_i$ converge rapidly to the correct values in this process, which is thus a successive approximation method of a special sort for fitting a 5th degree polynomial to $y_i(x)$ near x_o. During starting the interval is also decreased as necessary, so that when the process is complete the correct h as well as the correct $a_i \ldots d_i$ have been established. Thereafter, one meaningful forward step is

taken and control is returned to the link address. From the point of view of the user the first step is just like any other step except that (a) he must supply the initial conditions and the program parameter and enter by the "initial entry", and (b) it takes 24 or more times as long as other steps.

Complete details of the starting process and of the whole method in general are given in the paper "On Numerical Integration of Ordinary Differential Equations" referred to above.

(A. T. Nordsieck)

P 22 - 327 Mixed Number Output (DOI or SADOI). This routine converts numbers from a scaled double-precision two's complement representation and prints them in a sign-and-absolute magnitude representation, using print routine P16. The scaling in the original representation is such that the binary point is assumed to lie after the 2^{-39} digit, between A and Q. The part of the number in A is called the integer part, and that in Q is called the fraction part. The fraction part is always positive; the sign of the number is that of the integer part.

(John Ehrman)

V 14 - 323 Regular Spherical Bessel Functions. A complete discussion of the method may be found in the "Journal of the Association for Computing Machinery", Vol. 6, page 366 (July, 1959).

This program starts by choosing a k greater than N and assumes that $\bar{j}_k = 0$ and $\bar{j}_{k-1}$ is arbitrary. It then computes the ratios

$$\bar{r}_n = \frac{\bar{j}_{n+1}}{\bar{j}_n}$$

by using the recursion relation

$$\bar{r}_{n-1} = \frac{x}{2n + 1 - x\bar{r}_n} \; ; \; \bar{r}_k = 0.$$

When r_n becomes greater than one, the program starts to use the recursion relation for j's:

$$\bar{j}_{n-1} = \frac{2n + 1}{x} \bar{j}_n - \bar{j}_{n+1}$$

The $\bar{j}$'s so found will be proportional to the true j's. The proportionality constant α is

$$\alpha = \frac{\bar{j}_n}{j_n} = (\bar{j}_0 - x\bar{j}_1) \cos x + x\bar{j}_0 \sin x.$$

The true j's are then found using α and the ratios found before.

(R. Parsons)

V 15 - 324 Irregular Spherical Bessel Functions. The Irregular Spherical Bessel Functions satisfy the same recursion relation as the regular functions:

$$n_{k+1} = \frac{2k + 1}{x} n_k - n_{k-1}$$

The functions of order zero and one are:

$$n_0 = \frac{- \cos x}{x}$$

$$n_1 = \frac{- \cos x}{x^2} - \frac{\sin x}{x}$$

Since $n_k(0) = \infty$, n_0 and n_1 are computed using the trigonometric relations above (scaled by 2^{-12}), and the higher order terms are calculated using the recursion relation.

(R. Parsons)

V 16 - 326 Irregular Spherical Bessel Functions (Spherical Neumann Functions) (DOI or SADOI). The functions are computed using the formulas

$$n_0(x) = - \frac{\cos x}{x}$$

$$n_1(x) = - \frac{\cos x}{x^2} - \frac{\sin x}{x}, \text{ and}$$

$$n_{k+1} = \frac{2k + 1}{x} n_k - n_{k-1} \text{ for } k \geq 1.$$

(John Ehrman)

V 17 - 328 Reciprocal Gamma Function for Real Argument (DOI or SADOI). This routine is entered with X in A and link in Q. When the link is obeyed,

$$\frac{1}{\Gamma(x)} = x(x+1) \left[1 + B_1 x + B_2 x^2 + \ldots\right]$$

is in the accumulator, and x is at location zero. The variable x may lie in $-1 \leq x < 1$.

The Gamma function for other values of x may be computed using the relations

$$\frac{1}{\Gamma(x+1)} = \frac{1}{x} \frac{1}{\Gamma(x)} \qquad \text{and}$$

$$\frac{1}{\Gamma(x-1)} = \frac{x-1}{\Gamma(x)},$$ as well as many other relations which can be found in standard reference works on higher transcendental functions.

(John Ehrman)

Illiac Usage

During the month of September, specifications were presented for 15 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2051T. Numbers followed by T are for theses.

2051T Physics. Capture Cross Section for a Pair of Cloud Droplets Falling in an Electric Field. The purpose of the problem is to solve for the trajectories of the two cloud droplets falling at terminal velocities in an external electric field. This will determine the capture cross section as a function of their relative size and impact parameter (initial separation).

2052T Civil Engineering. Interaction of a Plane Dilatational Wave in an Infinite Medium with a Cylindrical Hole. The purpose of this problem is to determine the stresses in the medium around a cylindrical hole in an infinite medium when a plane dilatational wave intersects the hole moving in a direction perpendicular to its axis. It is proposed that the stresses will be found for an elastic medium and that a limited amount of study will involve the redistribution of stress when failure is allowed to occur in the medium at the regions of highest stress. The criteria for failure which will be used has not yet been determined, and probably cannot be until the elastic solution is completed. When the elastic solution is completed, it is proposed that it may be altered to include this failure region, at least in some approximate manner, and that the final portion of the work will involve alteration and reworking the elastic solution.

Solution to the problem will involve the superposition of stresses due to a plane dilatational wave and those from a diverging wave from a line source, such that on a fixed cylindrical boundary the radial and shear stress is zero at all times. Since there is no stress transmitted across this boundary, the material within it may be considered removed. Also the cylindrical wave becomes the reflected wave as it travels outward from the boundary so that the stress at any point outside the boundary may be found by the appropriate superposition of the two waves. This will be necessary for the latter part of the study.

In order to adjust the diverging wave so that the boundary stress is eliminated, the radial and shear stresses at the boundary for the plane and diverging wave are represented by Fourier Series with time as a variable in

each term of the series. Then each term of the series for the plane wave, which are known, are equated to the corresponding terms of the diverging wave and values of the latter determined for each time step.

2053 Psychology. School Motivation Analysis Test Standardization. The School Motivation Analysis Test is designed to measure various personality factors and their association to such things as scholastic achievement, delinquency and other behavioral variables. Illiac will be used to analyze a large amount of data collected from various sub-populations. Scores from approximately 1500 subjects will be checked for normality of distribution, correlated, factored and rotated.

2054 Psychology. Verbal Behaviors Related to Aspects of Teacher Leadership Behavior. This study is an attempt to ascertain if the concept of the additive effect of information bits can be applied to establish the "authority role" used by the teacher in conducting his classroom. The hypothesis was drawn that leader behavior as measured by the Leader Behavior Description Questionnaire was significantly related to four dimensions of authority roles which teachers may play. It was further postulated that these authority roles are related to the use or disuse of certain forms of speech.

The regression analysis shall be used to determine the internal consistency of the four postulated dimensions.

The oblique factor analysis shall be used to determine what relationships exist between the variables.

It is hoped to establish that the repetitive use of the common pronouns I, we, you, they and their derivatives lead to predictable perceptions of the leader role played by classroom teachers. It is further hoped to establish that the usage of these pronouns is associated with a syndrome of teacher behaviors.

Preliminary inspections of the regression analysis indicate a confirmation of the hypothesis that the aforementioned pronouns do indeed dimensionalize into perceived authority roles.

2055 Illinois State Natural History Survey. Celestial Orientation of Waterfowl. The problem is an experimental investigation of direction-finding by birds. Illiac will do statistical analysis of data by the method of least squares.

2056 Institute of Communications Research. The "Tenacity" Factor in the Semantic Differential. This particular study is concerned with the existence of a "tenacity" factor in "semantic space". In other words, it is hypothesized that the semantic differential, as it is presently being employed for the measurement and prediction of attitude change, does not take into account an attitudinal dimension which is called "tenacity" or "certainty of attitude".

Assuming that the above hypothesis is tenable, this added dimension would play a significant role in the determination of the point of maximal congruence which a given individual attempts to attain when confronted with dissonant attitudes.

Briefly, the experiment itself consisted of locating four groups of subjects (N = 80) on an attitude scale (i. e., the semantic differential). The subjects were then presented with persuasive messages advocating dissenting points of view concerning certain stereotypes and social issues. Then, an after-measure was used to determine the extent of attitude change produced by the experimental variable.

2057T Mechanical Engineering. Heat Transfer of Fluid Sphere. The heat transfer of a fluid sphere moving in a fluid infinite in extent is to be studied for the range of Reynolds number of 50 to 500.

The temperature distribution around the fluid sphere has been obtained analytically and values of local Nusselt number and heat transfer coefficient may be calculated, subject to the numerical evaluation of the resulting integrals, which depend on a parameter whose value is determined by the properties of the two phases of the fluid and Reynolds number.

2058 Medicine. Factorial Study of Moods. In conducting research on human behavior it is sometimes desirable to obtain measures of subjective responses such as mood. This study is directed toward defining some of the common dimensions of mood and identifying those scales which are most colinear with these dimensions.

In substance, a list of 133 adjectives which are descriptive of moods has been prepared. Each of four subjects, two men and two women, is using this list to describe his mood each day for 60 consecutive days. The subject describes his mood by rating each adjective on a four-point scale in terms of how well it "fits" his mood at that time.

Illiac will perform the following operations on each of the four sets of data, each set consisting of 60 ratings made by one subject on 133 adjectives:

1. Intercorrelate the 133 variables. (The data are the single unsigned digits 1 through 4, inclusive).
2. Factor analyze the correlation matrix by Thurstone's centroid technique. The communalities should be estimated by using the coefficient highest in absolute value in each row. Stop extracting factors when at least 90 per cent of the common variance has been accounted for. (Since KSL 1.20 cannot accommodate matrices of order greater than 111, 22 of the variables must be deleted. Selection of those to be deleted will be made after inspecting the correlation matrices).
3. Obtain two rotational solutions:
    a. Varimax.
    b. Oblimax, giving both reference vector structure and primary factor pattern in the output.

The results of these analyses will give information concerning the number of common dimensions involved in these ratings, the scales which most accurately measure these dimensions, and whether these dimensions and scales tend to vary among persons. These results will be applied to current research on the evaluation of drugs, to projected research on the autonomic nervous system, and to continuing study on the measurement of subjective responses.

2059 Civil Engineering. Dynamic Response of Simple-Span Highway Bridges. The problem consists of obtaining the response of a highway bridge, idealized as a uniform massless flexible beam with concentrated masses, due to the passage of an idealized vehicle. The computation is accomplished by a stepwise integration of the governing equations of motion. For the system considered, these equations take on the form of simultaneous non-linear differential equations with time-dependent coefficients.

Excellent correlation has been obtained in some cases between the observed behavior and that obtained by the program in its present form. However, correlation study referred to has shown that certain modifications in the program are required in order to extend this study.

The proposed modifications will permit the incorporation of more realistic parameters relating to the initial conditions of the vehicle as it enters the bridge and of an arbitrary profile of the bridge and its approach. The output will be modified to make the computed results more directly usable.

2060 Electrical Engineering. Resonant Electromagnetic Modes in Gyro Electric Plasmas. The solution of the characteristic equation for resonant modes in a gyroelectric plasma, of cylindrical geometry, is to be studied. The following equation will be solved for E.

$$\frac{\dfrac{AK_1(DE)}{DK_0(DE)} + \dfrac{AJ_1(\sqrt{AE})}{J_0(\sqrt{AE})}}{\dfrac{A(AC)K_1(DE)}{DK_0(DE)} + \dfrac{\sqrt{A}(A-C)(1-m^2) - J_1(\sqrt{AE})}{J_0(\sqrt{AE})}} =$$

$$\frac{\dfrac{BK_1(DE)}{DK_0(DE)} + \dfrac{\sqrt{B}\, J_1(\sqrt{BE})}{J_0(\sqrt{BE})}}{\dfrac{B(B-C)K_1(DE)}{DK_0(DE)} + \dfrac{\sqrt{B}(B-C)(1-m^2)\, J_1\,(\sqrt{BE})}{J_0(\sqrt{BE})}}$$

where A, B, C and D are simple functions of three parameters: plasma frequency, cyclotron frequency, and length of cavity.

2061T Education. An Identification of Structural Components in Learning. The purpose of this research is to identify mental abilities which differentially contribute to learning. Scores achieved on a battery of reference tests will be compared with performance scores derived throughout the learning sequence in order to locate points of interaction. The initial analysis of data will involve intercorrelation of all test and learning scores and perhaps a factorial analysis of certain variables.

Further aims of the study are to determine the patterns of mental abilities appropriate to performance of the learning task which are sampled by four differently structured learning conditions and to estimate the relative efficiency of these four styles of instructional presentation in terms of achievement in learning.

Total analysis of data, therefore, will necessitate the intercorrelation of test and learning measures for each of the four treatment groups as well as for the total sample group. In addition, it is desired that analyses of variance of certain variables across treatments will be examined in an attempt to identify the optimal learning condition.

2062T Physics. Absorption of Resonance Fluorescence. The physics problem involves the energy dependent absorption and scattering of protons. The energy dependence includes a very slowly varying part (electronic) added to a Doppler-broadened Lorentz line. Target thickness, absorber thickness, Doppler width/natural width, and peak nuclear/electronic absroptions are parameters.

The Illiac will be used to evaluate

$$I = \int_0^\infty \frac{e^{-rL\psi(x,t)}\left(1 - e^{-2t - r\psi(x,t)T}\right)}{1 + \frac{2}{r\psi(x,t)}}\,dx$$

$I = I(r, t, LT)$

where $$\psi(x,t) = \frac{1}{2(\pi t)^{1/2}} \int_{-\infty}^{\infty} \frac{e^{-(x-y)^2/4t}}{1 + y^2}\,dy$$

and where
r is peak cross section
L is absorber thickness
T is target thickness
t is Doppler ratio

2063T Chemistry. High Speed Polymer Generator. This work is a part of the continuation of previous high speed polymer generators. The new generator will be more efficient and faster than the old one in generating non-self intersecting polymers. The new method involves the generation of a polymer segment of thirty steps and then adding this successful segment to the part of the polymer already generated. If an intersection is observed on the computer, the whole segment is rejected and a new segment is generated. Polymers grow more efficiently in the above fashion than those generated by the old method, since intersections are most likely to take place within a segment.

2064 State Water Survey. Evaluation of Accuracy of Rainfall Amount by Dropsize Distributions. In this problem, the true rainfall rate (R) and the average rate

$$\left(\sum_{i=1}^{N} \frac{R_i}{N}\right)$$

will be computed and compared to (R), the rainfall rate as calculated from drop size distribution and regression lines (where $R^* = AZ^b$).

For comparison purposes, the error between the true and calculated rates and the variances of the individual R and R* will be computed.

2065 Psychology. Longitudinal Parent-Child Relations Study. The immediate research is the introductory phase of a ten year longitudinal study concerning pre-birth attitudes to parents' first child. The subsequent research will deal with the alteration of these attitudes as the prenatal child develops, matures and comes into contact with younger siblings.

Immediate research will deal with the development of inventories to assess parental attitudes. The computer will be used to obtain reliabilities and validities of questionnaire items and to factor the items to obtain cohesive sets of questions and define the particular areas with which the investigation is working.

The investigator does not foresee the necessity of any programs not existing in the statistical library at the present time.

Table I shows the distribution of Illiac machine time for the month of September.

TABLE I

	Hrs:Min	
Scheduled Maintenance	57:47	
Unscheduled Maintenance	27:43	
Drum Engineering	5:01	
Leapfrog	2:17	
Library Development	2:24	
Classes	7:18	
Instruction	:20	
Demonstrations	:28	
Wasted	:13	
		103:31

Use by Departments

	Hrs:Min
Aeronautical Engineering	6:00
Agricultural Economics	13:37
Agronomy (00 15 65 330 38)	2:37
Agronomy (ARS 46-15-15-317)	:02
Agronomy (0015-15-306)	:10
Agronomy	:15
Animal Science	6:51
Astronomy (NSF-G-14834)	:20
Bureau of Economics and Business Research	1:31
Chemistry (NSFG-5907)	17:14
Chemistry	63:47
Civil Engineering (NSF-G-6572)	:05
Civil Engineering (IHR-46)	:08
Civil Engineering	126:10
College of Medicine	10:30
Coordinated Science Laboratory (DA-36-039-SC56695)	62:04
Digital Computer Laboratory (NSF GRANT 9503)	5:34
Digital Computer Laboratory (NONR 1834(17))	29:00
Digital Computer Laboratory (AEC AT(11-1)-415)	:15
Digital Computer Laboratory (USTR AEC-1018)	:20
Economics (NSFG 7056)	1:02
Economics	:08
Education	1:59
Electrical Engineering (NONR 1834(22))	3:44
Electrical Engineering (NASA-NSG 24-59)	9:25
Electrical Engineering (AF 7043)	18:06
Electrical Engineering (AF 33(616) 6079)	:14
Electrical Engineering	3:43
Finance (IHR-71)	:31
Food Technology (50-343)	:35
Geological Survey	:21
Institute of Communications Research (44-28-20-378)	8:15
Institute of Communications Research (USPHM-3941)	4:14
Mechanical Engineering (DA-11-022-ORD 1980)	:02
Mechanical Engineering	11:49
Mining and Metallurgical Engineering (TRUS AF 6770)	:21
Mining and Metallurgical Engineering	2:46
Music	:52
Office of Instructional TV (OE 7-11-107.00)	1:12
Office of Instructional TV	2:16
Physical Education	2:15
Physics (GEN. ELEC. FELLOWSHIP)	:10
Physics (AF 49(638)-529)	:15
Physics (NONR 1834(05))	1:44
Physics (NAVY C)	:34
Physics	52:51
Psychology (MD 2060)	:45
Psychology (AF 41-657-279)	:10
Psychology	74:26
Sociology	9:59
State Water Survey	1:54
State Water Survey (DA-36-039-SC75055)	4:35

Theoretical and Applied Mech. (NOBS 72069)	:20		
Theoretical and Applied Mech. (DA-11-070-508-ORD)	18:14		
Theoretical and Applied Mech. (DA-01-021-ORD-11878)	6:33		
Williams College	2:37		
		595:27	
			698:58

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Memory	4
Input	3
Reader	2
Punch	2
Drum	10
Power	5
Scope	4
Printer Control	1
Unknown	2
TOTAL	33

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/1/61	20:50	1:05	2:05	1	(1) Drum failure.	:00	:00	0
9/2/61	20:02	3:58	:00	2	(1) +300 v fuse blew. (2) Broken resistor in memory power panel.	:00	:00	0
9/3/61	24:00	:00	:00	0		:00	:00	0
9/5/61	20:50	:00	3:10	0		:00	:00	0
9/6/61	18:58	1:25	3:37	2	(1) Drum failure. (2) Drum failure.	:00	:00	0
9/7/61	20:37	:53	2:30	1	(1) Unknown.	:00	:00	0
9/8/61	21:00	:30	2:30	1	(1) Scope check.	:00	:00	0
9/9/61	22:37	1:23	:00	1	(1) Drum failure.	:00	:00	0
9/10/61	24:00	:00	:00	0		:00	:00	0
9/11/61	19:49	:39	3:32	2	(1) Scope failure. (2) Punch failure, punch #1.	:00	:00	0
9/12/61	17:37	3:27	2:56	6	(1) Memory failure 2^{-23}. (2) + 65 v fuse blown. (3) Unknown. (4) Memory failure. (5)-(6) Will not read, reason unknown.	:00	:00	0
9/13/61	19:22	1:19	3:19	2	(1) Drum failure. (2) Failed to read, reason unknown.	:00	:00	0
9/14/61	18:58	2:32	2:30	2	(1) AC marginal failure. (2) Drum failure.	:00	:11	0
9/15/61	22:18	:00	1:42	0		:00	:00	0
9/16/61	24:00	:00	:00	0		:00	:12	0
9/17/61	24:00	:00	:00	0		:00	:00	0
9/18/61	20:24	:03	3:33	1	(1) Punch failure, punch #5.	:00	:07	0
9/19/61	20:35	:00	3:25	0		:00	:10	0
9/20/61	19:22	1:10	3:28	1	(1) AC marginal failure.	:00	:00	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/21/61	20:02	1:36	2:22	1	(1) Printer control trouble	:00	:08	0
9/22/61	21:00	:55	2:05	1	(1) AC marginal error	:00	:03	0
9/23/61	22:39	1:21	:00	1	(1) Drum failure	:00	:15	0
9/24/61	24:00	:00	:00	0		:00	:00	0
9/25/61	20:23	:11	3:26	1	(1) Reader error. Reader "B".	:00	:08	0
9/26/61	20:24	1:21	2:15	1	(1) Drum failure.	:00	:14	0
9/27/61	20:50	:22	2:48	2	(1) Reader error. Reader "G". (2) Scope error.	:00	:00	0
9/28/61	18:20	2:04	3:30	2	(1) Scope error. (2) Drum failure.	:06	:00	0
9/29/61	20:39	:17	3:04	1	(1) Memory failure. Location not noted.	:00	:24	0
9/30/61	22:31	1:29	:00	1	(1) Drum failure.	:00	:00	0
TOTALS	610:07	28:00	57:47	33		:06	1:52	0

PART VI

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

650 Executive System

A preliminary version of an executive (or automatic operator) system has been prepared for the IBM 650. In keeping with current procedure, the system has been called ATHOS. At present, the system provides an algebraic compiler (GAT--University of Michigan), an associated subroutine library, selective post mortem programs and control features for executing these and the object programs in a very flexible fashion. Student programs and production programs can be batched and intermixed. The executive routine will execute them whether they be in the problem oriented compiler language or in machine language. In the event of difficulty, automatic post mortem procedures will be called into play. The various passes of the system use magnetic tape as intermediate storage, and hence, no time consuming external card passes are required.

It is intended that a modified version of a symbolic optimal assembly program will be added so that a user of the system has complete freedom with respect to the language used in problem preparation.

(M. Cross, J. Flenner, R. Flenner, C. Wilmot)

New 650 Codes

During the month of September, one new routine was added to the Digital Computer Laboratory 650 Library.

K9' - 78' <u>Analysis of Variance, Covariance, and Multiple Covariance of Randomized Complete Block Designs with Single Degree of Freedom Analysis.</u> This program handles data obtained from Randomized Complete Block Design experiments; up to 9 sets of observations (or data fields) can be handled per problem, with a 10th data field available for use in conversions. The program computes and prints out non-zero treatment means for data fields 1 through 9. This is followed by computation and printing out of appropriate analysis of variance, covariance, or multiple covariance as specified. In the case of covariance and multiple covariance,

the unstandardized and standardized average error regression coefficients, the sums of squares due to regression, the inverse of the error crossproducts matrix, and the adjusted treatment means are printed out in addition to the adjusted treatment and adjusted error sums of squares and variances. For covariance analysis any of the 9 data fields may be the Y, or dependent variable, and any of the remaining data fields may be the x, or independent variable. Similarly, for multiple covariance analysis sub-problems any of the 9 data fields may be the dependent variable, and any of the remaining data fields may be independent variables. Thus, there may be 8 or fewer x variables.

Single degree of freedom analysis is optional for each sub-problem, and provides for factorial analysis of 1, 2 or 3 factors. The mean effect, mean square, and F value are printed for each single degree of freedom comparison in analysis of variance sub-problems. The absolute value of the adjusted mean effect, the adjusted mean square, and F value are printed for each single degree of freedom comparison in analysis of covariance and multiple covariance sub-problems.

There is no limit on the number of sub-problems. All data and the coefficients for single degree of freedom analysis are read in as fixed point numbers and converted to floating point for computations. Output is printed on-line on the 407 in fixed point form, with the exception of the inverse matrix which is in floating point form. The program uses a modified version of Library Routine M1' for matrix inversion, and R1' to obtain square roots needed in standardizing the regression coefficients.

(S. G. Carmer)

International Business Machines 650 Usage

During the month of September, specifications were presented for five new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 318'T. Numbers followed by T are for theses.

318'T Food Technology. Corn Quality and Uniformity. This research problem attempts to describe and determine chemical and physical measurements which may relate to quality and uniformity of whole kernel canned corn. Variables such as weight and size are used.

319' Agronomy. Establishment of Grasses and Legumes for Highways. The highway research problem has at present seven experiments to which analysis of variance should be applied. The analysis will be used on one sample to determine the differences due to combinations of species and fertility; on another, to determine differences in cover establishment due to the use of mulch and age of locust trees; on another, to differentiate the amount of cover, root growth and fertility reaction of 45 species; on another, to find the difference due to seed size, depth of planting and soil type in the establishment of crown vetch; on another, to determine if all sections of a highway bank receive the same amount of rainfall, and on others, to determine species response differences in cover establishment.

320' Agronomy. Oats Breeding. This research problem involves the testing of oats breeding lines and new oats varieties. This material is tested at four-five different locations throughout the state. Usually, the 650 will be used to calculate means and analysis of variance so that significant differences in the material may be determined. Data being analyzed will usually consist of the following: stand, lodging, height, yield and test weight.

321'T Institute for Research on Exceptional Children. Productive Thinking in Retarded Children. Retarded children (N = 71) and a contrast group of normal children (N = 27) were tested for productive thinking abilities. The test yielded 15 responses per subject. Pearson correlations (computed by IBM 650) will show relationships between these 15 variables and other variables, such as I. Q., reading level, arithmetic level, etc.

322' State Geological Survey. Gravity Data Reduction. Gravity data reduction consists of a number of similar steps in applying the total correction for each reading.

Each gravity value, when placed on a map, will aid in drawing a contour map of the distribution of the force of gravity in a particular area. When the variations in the gravitational force are known, certain deductions concerning geologic features can be drawn. Gravity maps are useful in the study of faults, buried topographies, orientation of dipping beds, domes, reefs and practically all major structures.

A series of gravity studies are to be made in Illinois by the State Geological Survey. These studies are hoped to be an aid in the economic development of the state and also to help in understanding the geologic history of Illinois.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of September.

TABLE I'

		Hrs:Min	
Scheduled Engineering		19:32	
Unscheduled Engineering		4:50	
Library Development		24:45	
Agronomy Library	2:43		
DCL Library	22:02		
Computer Operator		2:51	
Log Summary		:08	
Instructions		2:13	
Demonstrations		1:18	
Wasted		63:13	
			118:50

Use by Departments

Agronomy	6:30
Animal Science	5:29
Chemistry	8:24
Civil Engineering	8:00
Dairy Science	2:02
Electrical Engineering	38:29
Food Technology	2:10
Graduate College	12:54
Institute for Research on Exceptional Children	2:39
Mechanical Engineering	12:44
Small Homes Council	:08
State Geological Survey	1:57
State Water Survey	5:46

Statistical Service Unit		76:54		
Agricultural Economics	:35			
Agricultural Extension	3:16			
Bureau Institutional Research	4:58			
Bursar's Office	1:07			
Business Office	8:42			
Civil Engineering	:36			
DHIA	37:42			
Education	:33			
Forestry	1:04			
Horticulture	2:31			
Physical Education	:03			
Statistical Service Unit	1:47			
Student Counseling Service	14:00			
Theoretical and Applied Mechanics		3:09		
			186:75	
				306:05

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for September.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

533 card read punch		2
Pilot selector	1	
Bent connector	1	
650 console		8
Lost bits	4	
Clock	3	
Clocking	1	
653 high speed storage, floating point, index registers		5
False storage unit lights	5	
727 tape units		2
Read error	1	
Unit not unloading properly	1	
TOTAL		17

TABLE III

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
9/1/61	15:04		:10	:44	3	(1) Lost distributor sign. Upper accumulator blank. (2)(3) Lost bit in pos. 1 of distributor due to clock working improperly.
9/5/61	9:57	4:03		1:10	1	(1) Pos. 1 of distributor blank due to clock working improperly (three times).
9/6/61	10:28	3:28		1:26	0	
9/7/61	11:29		2:21	2:21	2	(1) Clocking circuit not working. (2) False storage unit light.
9/8/61	12:57			3:14	2	(1) False storage unit light. (2) Tape read error after 50 tries.
9/11/61	11:21	4:03		:47	0	
9/12/61	14:59			:57	0	
9/13/61	15:12			:44	0	
9/14/61	8:12			3:48	0	
9/15/61	4:46			5:44	0	
9/18/61	3:48	4:01		6:14	0	
9/19/61	6:36		:22	7:53	2	(1) Tape unit 1 does not unload properly. Unit oiled. (2) Lost a quinary bit in pos. 10 of distributor.
9/20/61	10:35			5:15	1	(1) Pos. 7 of program register blank.
9/21/61	12:48			3:14	2	(1)(2) False storage unit lights.
9/22/61	8:32			6:53	2	(1) False storage unit light. (2) Lost quinary bit in pos. 3 of distributor.
9/25/61	6:08	3:57		4:54	0	Scheduled engineering resulted in finding a bad tube unit which would cause false storage unit lights.
9/26/61	12:36			3:30	0	

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
9/27/61	13:07		1:47	1:06	1	(1) Pilot selector 1 not working on 533 due to open pic coil in pilot selector #2 relay.
9/28/61	15:35			:49	0	
9/29/61	14:20		:10	2:30	1	(1) Bent connector in 533.
TOTALS	218:30	19:32	4:50	63:13	17	

PART VII

GENERAL LABORATORY INFORMATION

Seminars

"Model of a Partial Switching Effect in Ferrite Cores", by Dr. Sylvian R. Ray, University of Illinois Digital Computer Laboratory, September 25, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	13	0	13.0
Research Associates	8	0	8.0
Graduate Research Assistants	1	31.0	13.0*
Graduate Teaching Assistants	0	3	.75
Administrative and Clerical	6	0	6.0
Other Nonacademic Personnel	39	14	45.95
	67	48	86.70

*Most assistantships begin September 15.

The Laboratory Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - CIRCUIT RESEARCH PROGRAM

PART III - MATHEMATICAL METHODS

PART IV - DATA REDUCTION METHODS

PART V - ILLIAC USE AND OPERATION

PART VI - IBM 650 USE AND OPERATION

PART VII - INSTRUCTIONAL USE OF COMPUTERS

PART VIII - GENERAL LABORATORY INFORMATION

October, 1961

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Construction Progress

Table I summarizes the progress during the month toward completion of the computer. Entries in Table I indicate the number of transistors which have completely passed through the phase of design or construction indicated by the column heading. Within one rectangle of Table I, the three figures from top to bottom indicate completions, respectively, at the beginning of the month, during the month, and at the end of the month. The transistor counts are intended to reflect the amount of work directly applicable toward completion of the computer, rather than total effort expended. For example, if the wiring of a chassis has to be modified, it is removed from the "completed" list, and indicated as having been wired again during the month in which the modification is made.

Completion of systems design indicates that the general strategy of design has been worked out in some detail. For a control, for example, a mnemonic order code would be fixed on completion of systems design, although the numerical equivalents for each order would be unknown. Logical design completion would be indicated by a logical diagram in which circuit restrictions on fanout and cascading are observed, but physical distances and consequent cable driver circuits are not included.

Physical placement is completed when chassis boundaries are fixed, and cable driving circuits included in the logical diagram. In block layout, the function of each transistor on a chassis is indicated by circuit block symbols. Information sufficient for drafting, frame wiring, component layout, and power supply requirements is available on completion of block layout.

Component layout requires as many as 14 drawings for each chassis, showing successive phases of wiring of the chassis.

Table I

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Drafting	Subsystems Test	Systems Test
Repetitive M.A.U. 5380	5379	5379	5379	5379	5379	5379	5379	5379	5379	5379	
Core Storage Unit (4096) words) 3883	3883	3883	3883	3883	3883	3883	3883	3823 60 3883	2150 2150	0	
Delayed Control EAU, End Connections 11200	11200	11200	11200	4296 914 5210	2030 1454 3484	694 1970 2664	694 1288 1982	8 90 98	630 395 1025	0	
Flow-Gating (Buffer Storage) 3987	3987	3987	3987	3987	3832 155 3987	3572 415 3987	3572 415 3987	3572 415 3987	3789 53 3842	0	
Advanced Control 7000	7000	2100 0 2100	0								
Drum Storage Unit 2500	2500	1370 0 1370	0								
Interplay Control 3000	3000	0	0								
Paper Tape Input-Output 641	641	641	641	641	508 133 641	0 508 508	0 319 319	0 0			
Test Controls	1434	1434	1434	811 623 1434	811 623 1434	438 821 1259	438 606 1044	438 183 621	438	438	
TOTALS	39024	29994	26524	18997 1537 20534	16443 2365 18808	13966 3714 17680	13996 2628 16594	13220 748 13968	12387 448 12835	5818 0 5818	0

The static test involves application of D.C. power to the chassis before transistors are plugged into sockets. Voltage measurements at all nodes indicate faulty components, wiring errors, etc., not caught during visual inspections.

The column headed drafting indicates the completion of circuit schematics only. Thus, considerable drafting effort, such as preparation of logical drawings, figures for reports, etc., is not reflected in Table I.

A subsystems test is a dynamic test of several thousand transistors using a relatively simple fixed program usually generated by a small special purpose control to be discarded later. Systems tests can occur when sufficient equipment is assembled to run programs read from punched tape.

2. Circuits

On the basis of measurements made by R. L. Cummins in September-October, a design for a fast zener diode bleeder to be used in "EXCLUSIVE-OR" circuits was evolved. A tolerance design was subsequently made for a range of output bump levels and will appear as a modified drawing B-942 in the circuit book. It should be noted that this bleeder and associated diode "AND" circuit, though entirely adequate for the required job within the "EXCLUSIVE-OR", should not be used in certain more general collector logic circuits, particularly those in which nominally complementary signals are applied to the logic diodes. A more detailed discussion on related matters exists in File No. 415 by G. Metze.

Based largely on measurements made by R. L. Cummins, a File No. 410 was prepared on "Precautions to be Observed when Driving both Restoring and Nonrestoring Circuits from a Single Emitter-Follower". This tells of the possible slow-down of fast nonrestoring logic by its association, in the manner indicated, with inverting, restoring circuits.

Experiments were carried out, once more, on various aspects of twisted pair cables. Results are generally somewhat hard to generalize but certain facts have arisen. Twisted pair formed from teflon-insulated (.057 inch OD), 22 gauge wire, with .8 to 1.2 twists per inch was measured in 30 to 60 foot lengths to have an impedance of $130\,\Omega \pm 5\%$ and a delay of 1.33 to 1.36 nsec per foot. A reflection

effect, which appeared to imply a reactive component of cable impedance, was observed which tended to make termination resistance measurements somewhat different depending on the end of the cable at which they were made. The value which "best" terminated the receiving end was chosen as best suited to the present application. Reflections on simple transmissions over a 30 foot terminated cable appeared to be less than 5%.

Results related to noise induced on twisted pair are less straightforward. First it appears impossible, in a finite time, to add more information than has already been obtained by M. Melman on short cables (2 feet) concerning "incoherent", "random-source" noise. This is related to the difficulty of generalizing such results to a longer cable.

Secondly however, some more concrete results are available concerning what may be labelled "coherent" noise. This results from the capacitive coupling of twisted pairs which parallel each other for a large distance, (their entire length in the particular case investigated). This coupling, which may be discussed later in a file number report, consists of the existence on the receiving pair of a small flat-top pulse, of length equivalent to twice the cable delay, which is produced by a step wave on the transmitting pair. This pulse results when the signal conductor of the receiving pair is charged, relative to its ground wire, by the transmitted step. The pulse is formed on the receiving line, which, for our particular desired mode of operation, is terminated at the receiving end only, in a manner equivalent to pulse formation in a relay pulser.

The pulse amplitude depends on the transmitted signal swing, and the cable spacing. For a 5 volt step transmitted and 1/2 inch spacing, 0.5 volt noise pulses were observed. It should be emphasized that this noise amplitude will exist essentially independent of cable length and will only be attenuated for those cases in which the signal rise time is long compared to the cable delay. This threshold occurs at about 2 feet for typical 15 nsec rise pulses.

In conclusion it would appear that any cable length in excess of 2 feet is as bad as another and that in particular 30 feet is no worse than 10 feet. Thus in main frame wiring, where 1/2 inch spacing at least is allowed, twisted pairs seem reasonable if 1/2 volt extra noise margin is available. It is emphasized that noise from random sources may also build up at some time and

place to be troublesome, and is neglected in this conclusion. The alternatives of using 130 ohm coax and/or using a transistor with higher power rating, with slight circuit change, as a driver, would seem to indicate the continuance of present techniques of signal distribution, until concrete evidence of difficulty is seen.

In addition to the experiments noted for a terminated cable, measurements were also made on the reflections present in unterminated, short (2 ft.) lengths of twisted pair. One example of the behavior expected is described in File No. 414 "Some Effects of Driving Unterminated Twisted Pairs by Emitter-Followers". This report treats, in detail, only the case of positive going signals. The behavior for negative swings, which was inadvertently omitted from File No. 414, is perhaps worse in some respects. In each case it can be demonstrated that "undershoot" signals, constituting a local tendency toward signal reversal, may occur under certain signal conditions with amplitudes of 0.5 to 1 volt. Noise of this type will also be present on single wires, which if considered as a high impedance line, will produce signals that may be more easily deteriorated and smoothed by load capacitance.

In this case also, when the typical circuit rise time is considered, the two foot wiring limit previously chosen appears to be a reasonable compromise between production of noise and ease of layout.

(K. C. Smith)

3. Core Memory

The wiring of the core memory frame was completed except for minor details.

The control circuits, sense amplifiers, digit drivers and X-Y drivers were checked out. The lower half core stack was then put in place. One word was then operated in order to check the dynamic operation of the sense amplifiers and digit drivers. This checkout was completed at the end of the month.

(S. R. Ray)

4. Advanced Control

The general area called Advanced Control contains a variety of equipment, some of which need not be built until Interplay is added. This equipment will be described.

4.1 Memory Control

This processes requests for the 2 core memories originating in Advanced Control proper, the drum section of Interplay, and the remainder of Interplay. This equipment, which is planned to be installed above the core memory at the time Interplay is added, assigns priorities, routes addresses and full words to memory, makes the actual memory requests, and generates appropriate replies for the requesting devices. This part was designed during the month by R. R. Shively. Memory Control also includes the so-called CAOK Block Checker, designed previously, which determines whether an Advanced Control reference to memory refers to any 256-word block which is involved in an Interplay block transfer. An illegal reference causes a read-out (whether or not a write was called for) and the setting of an error flipflop suitable for program interruption.

4.2 Address Arithmetic Unit

This consists of approximately 1950 transistors to be located in the main frame at the Q, A, S levels of bays 10, 11, 13, 14 front. During the month certain simplifications were made, and the design was finalized by M. Faiman. Some of the equipment formerly assigned to this area was transferred to Memory Control to reduce the amount of construction required for an Advanced Control operating without Interplay. A preliminary block layout was made by M. Faiman, K. Mikami and D. B. Gillies.

4.3 Gate and Selector Decoders and Mechanisms

The largest mechanisms are those associated with the control of the Flow-gating memory. An address in this memory is either fixed, namely F0 or F1, or is defined by one of the registers DD, EE, BB, WB, WAB of 3 or 4 bits each, and a decoder which should be designed at the same time as the mechanism. The input control equipment gF, and the output control equipment sBS, was revised and redrawn by K. Fuchi and R. R. Shively. For the AAU, the adder input mechanism sAD was designed by K. Mikami and its output selector sAB (for the return path to Flow-gating) was designed by K. Fuchi.

4.4 DD/EE Counter

This 3-bit, double rank counter is used for cycling through the quarter-words contained in the instruction buffer registers F8 and F9, and it is also closely related to the operation of fetching a new pair of words. DD/EE and the control area functionally adjacent to it was designed by K. Mikami and revised by R. R. Shively and D. B. Gillies.

4.5 Auxiliary Sequencing Controls

The controls

a) Store Control (SCO, used to complete the transfer of a word from the Core Memory to the IN register)

b) Out-Write Control (OWC, used to complete the transfer of a Delayed Control result from the OUT register to its final destination in Core Memory or Flow-gating Memory)

c) Control Counter Control (CCC, used to load 2 words from Core Memory into registers F8, F9 and advance the contents of the Control Counter register CC by 2)

were designed during the month by R. R. Shively.

4.6 Main Decoder and Sequencing Control (SAC)

During the month, in preparation for the final design of these units flow charts were redrawn by D. B. Gillies, and the corresponding decode conditions associated with each step where checked by M. Faiman and K. Fuchi. Further checking and simplification of decode conditions is required before design of the decoder can begin.

5. Magnetic Drum Memory

On October 10 and 11, the first of the two magnetic drums was inspected at Vermont Research Corporation, Springfield, Vermont. The working parts of the drum were complete and functioning, although the enclosure, mounting and most of the heads were not installed. All of the parameters observed met or exceeded our

purchase specification except for amplitude modulation and resolution which were slightly out of limits. AM was 13.5 percent on the worst track, where < 10 percent is required. Later in the month, VRC recoated the rotor, and reported that the maximum AM was reduced to 6.5 percent, and the resolution was increased to .80, where > .75 is required. Delivery, originally scheduled for September 15, is now expected during November. When the drum arrives, some of the first experiments performed will be those related to pulse crowding and pulse shape so that the read amplifier and detector design can be completed.

(H. C. Brearley)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

T. Moto-Oka worked on a new theory of switching times in tunnel diode circuits. H. Guckel pursued his tunnel diode work by simplifying the 2000 mc counter: the latter is now of the latch type. Preliminary layout of the counter was achieved.

J. Hill made progress in failsafe circuits, especially as far as failure indication is concerned. It turns out that considerable savings in hardware can be obtained if the transistors are tested continuously by a dc-operating point detector; the transmission of information must then rely on ac-coupling.

T. Burnside resolved some of the mathematical difficulties encountered in reliability studies using probability distribution curves. In particular a method was found to treat the simplest nonlinear problems involving a "statistical" diode in series with an "ideal" resistor and fed from a source with a known voltage-probability characteristic.

S. Ribeiro continued his study of the theory of supersaturation. Fairly good agreement was reached between the theoretical gain formula and data taken on GF45011 and S166 transistors.

The reports on Moto-Oka's and Burnside's work will appear next month. All other investigations are reported on in more detail below.

2. 2000 MC Counter

Emphasis in the work on tunnel diodes has been shifted from individual circuits to interconnections. A section of strip line was made by using a double-sided printed circuit board and depositing a copper sheet as shown in Figure 1. This allows variations of lateral dimensions in order to study the characteristic impedance and pulse response of a layout. Some other experiments have been conducted in connection with hand etching of copper clad ceramic boards.

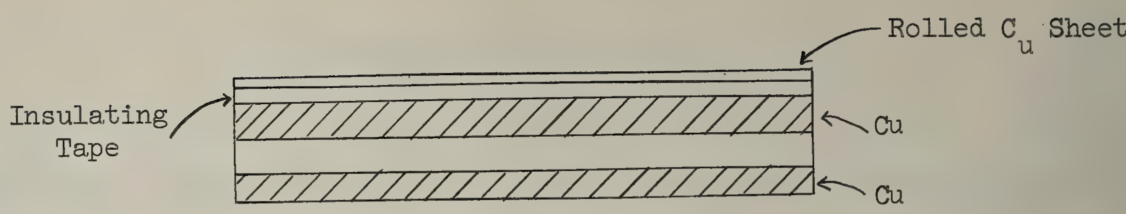


Figure 1

Production of Strip Lines

The counter reported on earlier has been simplified, it is now a latch counter, as shown in Figure 2. This modification is due to a) a limited amount of available diodes, b) difficulties in the design of NOT circuits. The counter works by changing the state of all latches to the same state with successive pulses and then resetting them successively by changing to a negative going pulse output instead of a positive going one.

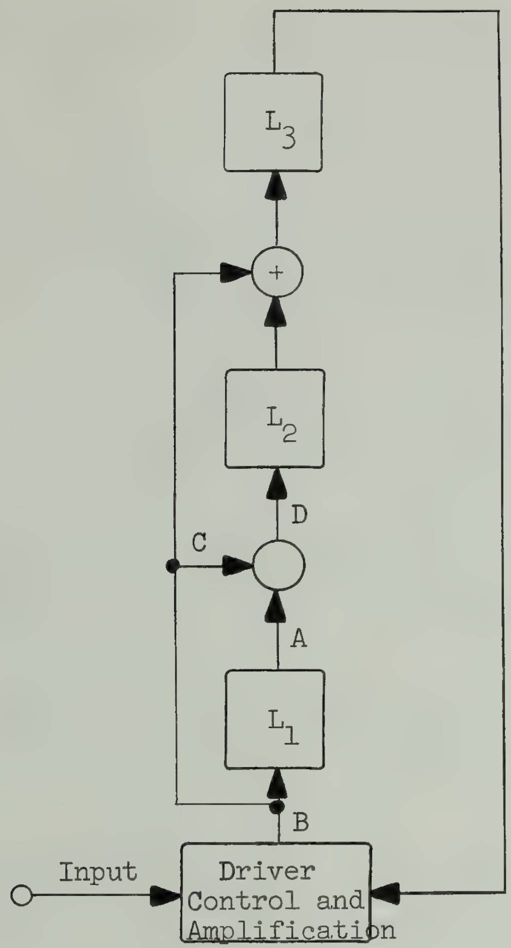
Figure 3 shows the operating diagram of an AND circuit. If i_p and i_v are the peak and valley currents respectively and f(v) symbolizes the characteristic it is not difficult to see that in the notation of Figure 2 the condition for this circuit to be able to drive latch i + 1 when it is driven by latch i is:

$$\frac{(v_1)_i}{R_1} = \frac{V_1}{R_3} + \frac{(v_0)_{i+1}}{R_2} = \Big(f(v)\Big)_1 > i_p \qquad \text{(Solution } S_1\text{)}$$

$$\frac{(v_1)_i}{R_1} + \frac{V_0}{R_3} + \frac{(v_0)_{i+1}}{R_2} = i_v < \Big(f(v)\Big)_0 < i_p$$

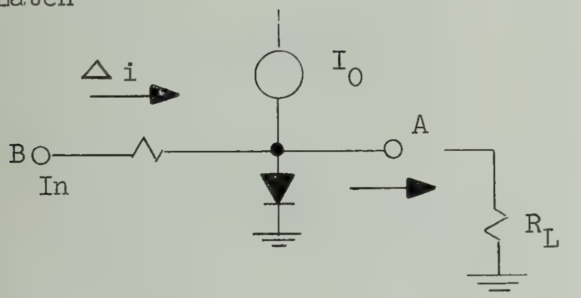
For the switching from $1 \rightarrow 0$ the roles of stage i and i + 1 are exchanged. The inductor was inserted to allow for incorrect switching pulses from the device.

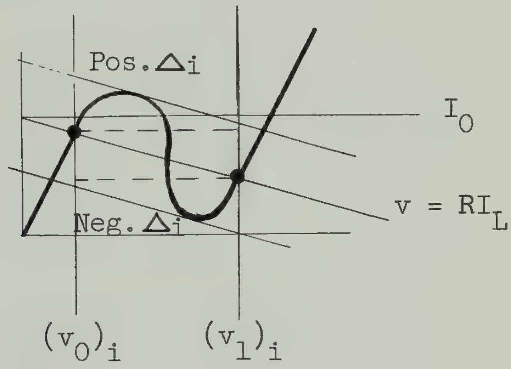
The driver in Figure 2 is essentially formed of the layout shown in Figure 4: The input signal gives rise to two different outputs which are controlled by two gating signals G and G' offset dc-wise but identical as to their variations. The operation of the whole system will be explained in a subsequent report.



Circuits

a) Latch





b) AND Circuit

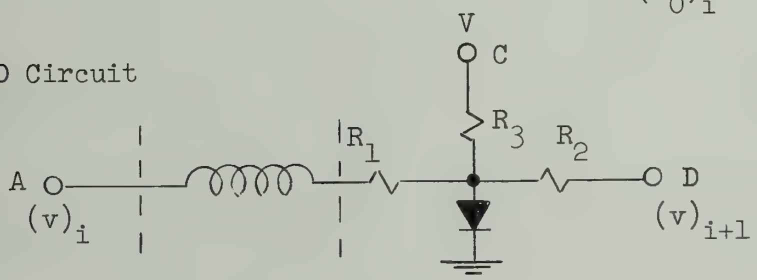


Figure 2

Latch Counter

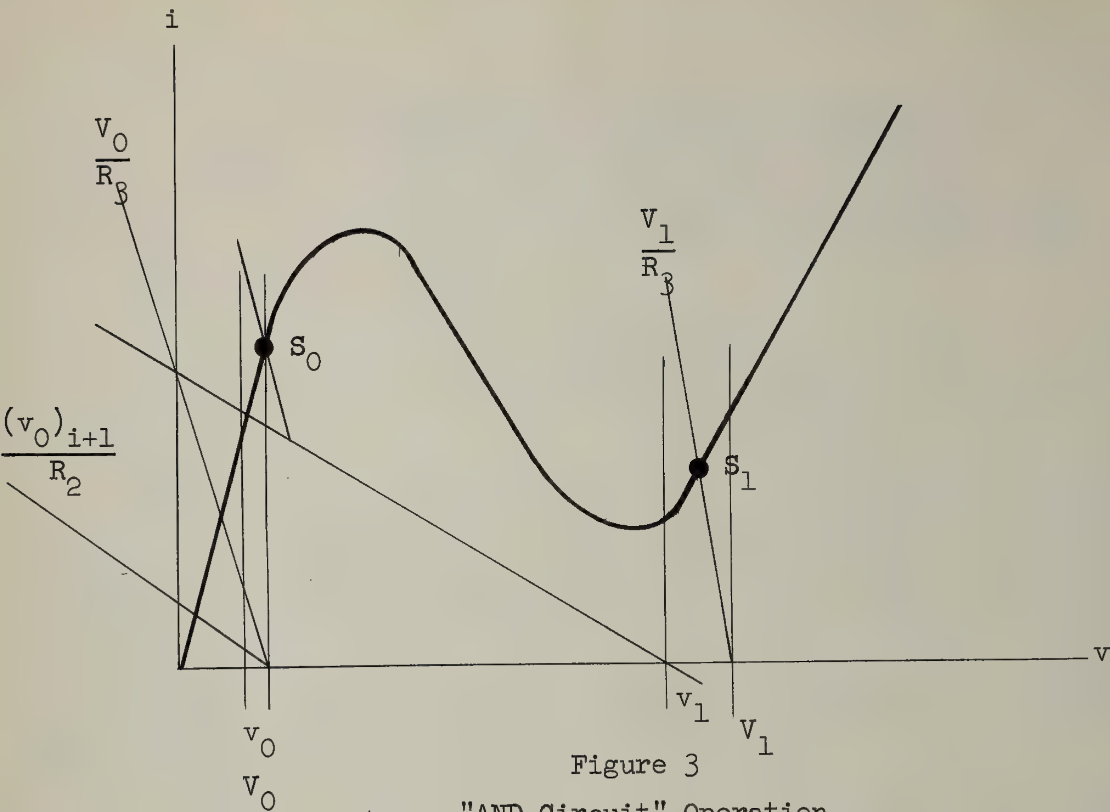


Figure 3

"AND Circuit" Operation

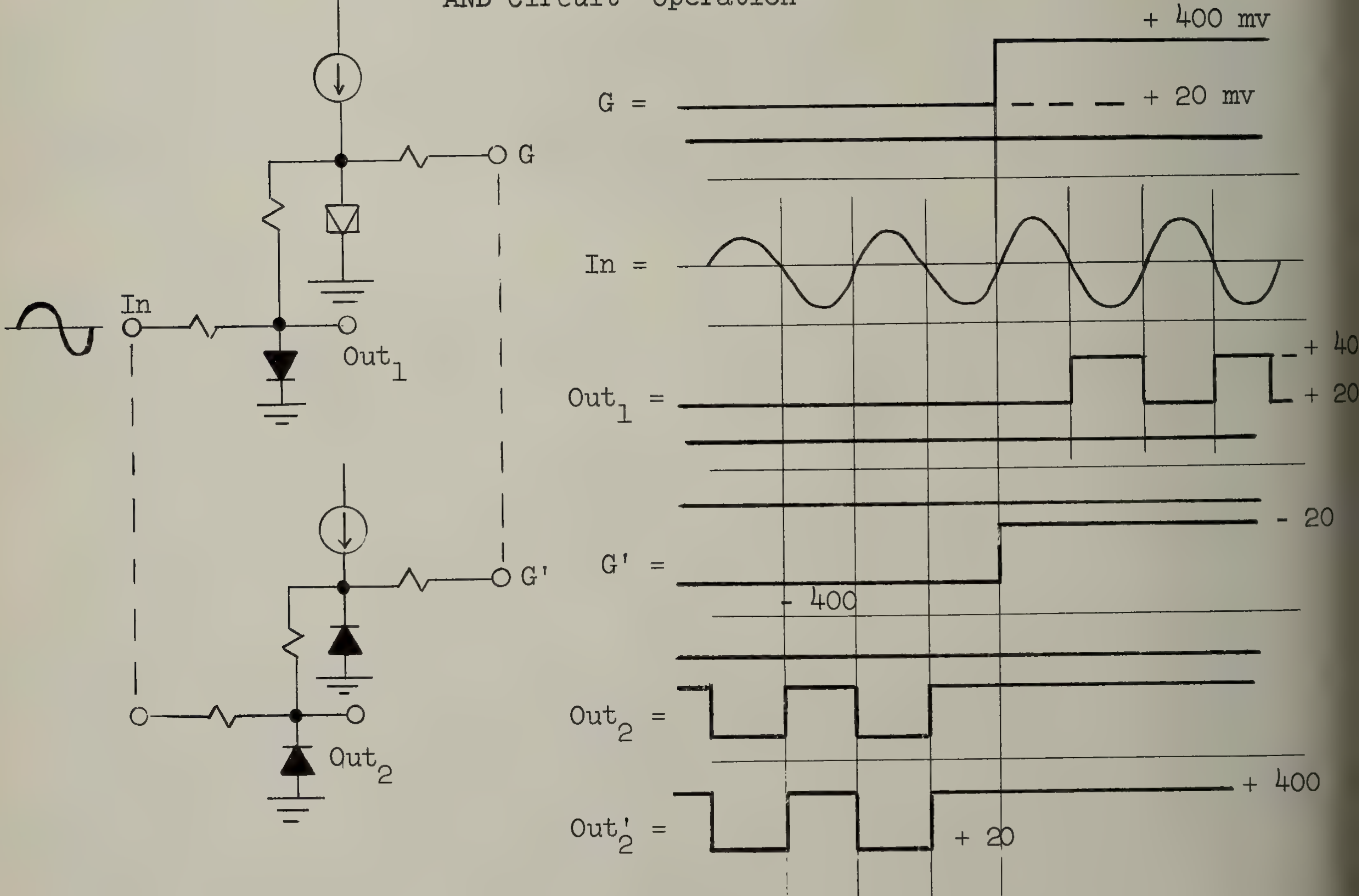


Figure 4

Counter Driver

3. Supersaturation

Frequency response data taken on a GF45011 checked the tentative equation:

$$G_I = \frac{\overline{i_{E\sim}}}{\overline{i_{C\sim}}} = \frac{1}{\left(\frac{R_E}{\rho}\frac{I_{BO}}{I_{EO}} - 1\right) + S\tau\left(\frac{r_E}{\rho}\frac{I_{BO}}{I_{EO}}\right)} = \frac{1}{(\gamma - 1) + S\tau\gamma}$$

where $R_E = r_E + r_L$ is the total resistance of the emitter current.

ρ = dynamic resistance of the emitter base junction.

I_{BO}, I_{EO} = base and emitter biasing currents, respectively.

τ = minority carrier lifetime in the base.

S = complex frequency.

$\gamma = \frac{R_E}{\rho}\frac{I_{BO}}{I_{EO}}$, a convenient parameter.

The equation can be presented as below, for purely sinusoidel excitation:

$$G_I = G_b \cdot \frac{1}{1 + j\frac{f}{f_0}}$$

with: G_b = low frequency gain: $G_b = \frac{1}{\gamma - 1}$

f_0 = cutoff frequency : $f_0 = \frac{1}{2\pi\tau(G_b + 1)} = \frac{\gamma - 1}{2\pi\tau\gamma}$

Experiments:

r_L was adjusted so that $\gamma - 1 > 0$: $r_L = 4.7\Omega$. The following data were obtained: $G_b = 6.8$, $f_0 = 800$ cps.

f (cps)	100	200	400	800	1600	3200	6400
G_I (db)	0	-.3	-1	-2.5	-6	-12	-18.5

from these data we get

$$\gamma = \frac{G_b + 1}{G_b} = \frac{7.8}{6.8} = 1.15$$

$$\tau = \frac{1}{2\pi f_0 \,(G_b + 1)} = \frac{10^{-3}}{6.28 \times 0.8 \times 7.8} \approx 26 \ \mu\text{sec.}$$

Comments:

It should be pointed out that:

a) For small values of R_E (say $r_L \rightarrow 0$) the system becomes unstable, which checks, qualitatively, with the right-hand pole contained in the equation, for $\gamma > 0$.

b) For large values of R_E, no gain is obtained (i.e., $G_I < 1$).

c) For intermediate values of R_E (say, $r_L \approx R_E$) such as the one we used, we get moderate gains.

d) Some difficulty in keeping the DC amplifiers balanced is responsible for a relatively large error, which, however, is of no consequence for our purposes.

To improve the situation pointed out in d) above, a small low-pass transistor amplifier was constructed to keep the DC amplifier (at the emitter side of the test transistor) automatically balanced.

Other transistors were tested to see if they would present the same effect: GE-2N188A; M-2N-651; TI-S166. Only the TI-S166, which is similar to the GF45011, presented the effect of $|G_I| > 1$ within the range of the instrument.

A low frequency oscillation occurs at the points where (prior to automatic balance) the DC amplifier could not be balanced at the emitter side of the test transistor. These oscillations (order of a few cycles per second) are related to the presence of a large capacitor at the collector of the test transistor, and they disappear if the collector voltage is forced to stay constant.

4. Failsafe Circuits

Simplified failsafe logic circuits have been developed by using AC instead of DC coupling. In these circuits a positive pulse represents a "1", a negative pulse a "0", and the absence of a pulse conveys no information. This two level use of an essentially three level scheme permits the design of redundant circuits that use only twice as many transistors as standard circuits. An example of an emitter-follower utilizing this principle is shown in Figure 5.

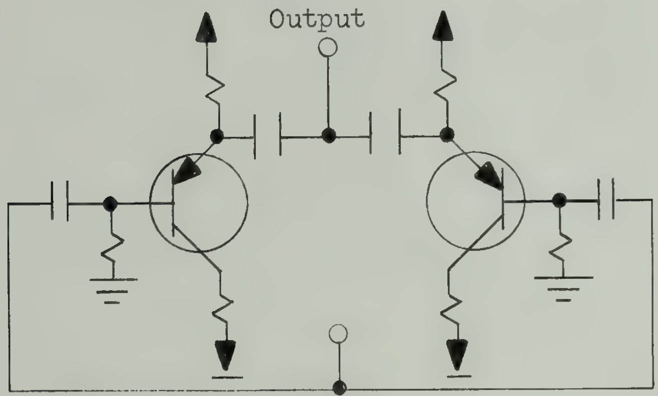


Figure 5
Failsafe Emitter-Follower

In this circuit any single capacitor, resistor or transistor may fail (open, wrong value, or short) and the circuit will still function properly. This concept of AC coupling may be extended to make an "OR" circuit by connecting two emitter-followers together at their outputs. When PNP transistors are replaced by NPN and the supply voltage polarities reversed the "OR" circuit becomes an "AND" circuit. Voltage amplification and the "NOT" operation may be obtained by using pulse transformers as coupling elements.

An advantage of using pulse logic is that it leaves the DC operating point of each individual transistor free for the testing of its operation. Figure 6 shows the general DC circuit configuration of a transistor with a low power absorbing light bulb (thyratron light) attached to its emitter. This circuit can be designed so that any arbitrary combination of transistor opens

and shorts will cause the bulb to light, indicating a failure. Note that, even though the lit bulb indicates a necessary replacement or circuit repair, the circuit still continues to function properly.

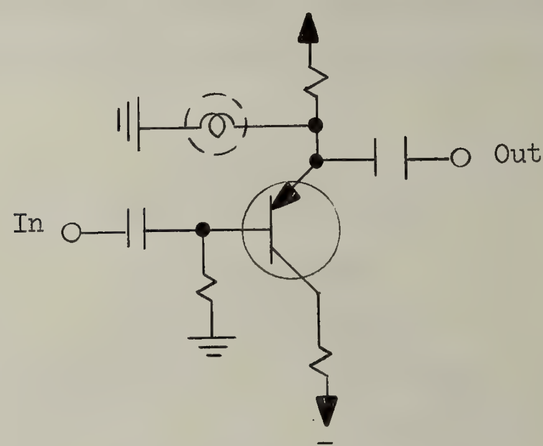


Figure 6

DC Failure Indication

PART III

MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Monte Carlo Methods in Quantum Statistics

The program (NUMBER 6) for calculating the two-particle partition function was revised slightly to accommodate a wider range of parameters. This new program is called (NUMBER 6.2). The principal difference between 6 and 6.2 is that the latter permits a slightly more accurate numerical integration, by permitting more integration steps.

The program (NUMBER 6) was used to calculate $\frac{F}{R}$ (see September Technical Progress Report) for some additional cases with $\frac{\lambda}{\ell} = \frac{1}{8}$ (the ratio of the mean wave length of the particle to the box dimension). Some of the results of these computations are given below; this is simply a continuation of the table in the September Technical Progress Report.

$\frac{\lambda}{\ell} = \frac{1}{8}$ $\frac{F}{R}$ (exact) = 0.9039

$\frac{F}{R}$ (Monte Carlo) Tabulated as a Function of n and N

n \ N	100	200	300	400	500
10	0.950	0.940	0.950	0.952	0.944
20	0.930	0.945	0.950	0.948	0.942
30	0.890	0.920	0.933	0.932	0.922
30*	0.940	0.920	0.910	0.905	0.914

* A different random number sequence was used.

The parameters used here were defined in the September Technical Progress Report. The higher accuracy of these results compared with those reported last month is due to the smaller value of $\frac{\lambda}{\ell}$. It will be recalled that the classical limit is approached as $\frac{\lambda}{\ell} \longrightarrow 0$. Since the program is designed to give the correct result in the classical limit the higher accuracy seen here is not surprising.

(Supported in part by the National Science Foundation under Grant G16489)

Round-Off Procedures

The effects of round-off error in solving scalar equations iteratively are being studies. A method of round-off related to that proposed by A. T. Nordsieck has been shown to lead to better numerical results than the usual round-off procedure used in fixed point computers.

Let us consider the equation $F(X) = 0$ of root a and the following iterative process

$$X_{n+1} = X_n + G(X_n).$$

Suppose that the only representable numbers on the computer are of form $Y_n \in A$ where

$$A = [N \cdot 2^{-m} \quad N = 0 \pm 1, \pm 2 \ldots].$$

Our effective process may be written

$$Y_{n+1} = Y_n + \widetilde{[G(Y_n)]}$$

where $\widetilde{[\ ]}$ means a particular rounding to be defined below.

Let $[\ ]^{\nearrow}$ mean rounding away from zero i.e. $|[X]| \geq |X|$

$[\ ]^{\swarrow}$ mean rounding towards zero i.e. $|[X]| \leq |X|$

and
$$\widetilde{[X]} = \begin{cases} [X]^{\nearrow} & \text{if } |X| \leq 2^{-m} \\ [X]^{\swarrow} & \text{if } |X| \geq 2^{-m}. \end{cases}$$

We defined the gain $g(X_n) = \dfrac{X_n - a}{X_{n+1} - a}$ and we suppose that $g(X_n) > 1$

Then: 1) If $a \in A$, there exists a finite number K such that

$$Y_n = a \quad \text{for } n \geq K.$$

2) If $a \notin A$, there exists a finite number K such that

$$\left.\begin{array}{l} Y_{K+2i} = \xi \\ Y_{K+2i+1} = \eta \end{array}\right\} \quad i = 0, 1 \ldots$$

where $\xi, \eta \in A$, $\xi < a < \eta$, $\eta - \xi = 2^{-m}$.

A report containing the proof of this theorem is being written.

(J. Descloux)

PART IV

DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. Simulation of Pattern Recognition Unit (PRU) on Illiac

A simulation of the PRU, described in File No. 403, is being written for the Illiac Computer. The 2-dimensional shift plane is 112 x 112, with 16 bit stalactite and buffer registers provided for an 80 x 80 field. A program on the simulator comprises PRU orders, and "serial computer" subroutines written in the normal Illiac machine language. The felxibility of end connection logic (for transfers with logical operations between the end bits of the stalactite, buffer, and the 2-dimensional S-plane) has been greatly extended from the design in File No. 403. A single PRU instruction, (e.g. bubble 1's up M cycles) is estimated to take 5-8 seconds, depending on the order. A set of 20 idealized input patterns have been hand key punched. Trial programming to run on the simulator is in progress.

W. Carskadon, R. Narasimhan, J. Stein

II. Minimal Cost Template Covering Algorithm

The optimal encoding conjecture for describing a picture in terms of a minimal cost template covering (File No. 380) is under detailed investigation and computer simulation. An algorithm for systematically finding the minimal cost covering of a digitized photograph, given a priori a set of costs for each template type, has been found. Introducing the transpose of the covering matrix a dual covering is suggested, with the dual covering sets specified by each point X_i, in turn, of the original photograph and containing as points all templates "covering" X_i.

A set of covering matrices have been computed by hand from samples of bubble chamber film for a variety of template shapes.

B. Mayoh, S. Narkinsky

III. Language for Scanner-Computer Communication

We intend to monitor a scanning desk with a low resolution recording camera, such that scanner designated areas, classification of objects, and in general other explanatory information about the photograph can be recorded and later scanned by the CRT prior to analysis of the original image. The conventions and notation for transmitting this "grease pencil" information from the monitoring camera film to the CRT Scanner system can be considered a formal language. A first language of this type is being formulated.

H. Zar

IV. 105mm Optical Assembly

Preliminary drawings for an optical assembly to hold the CR tube, lens, and camera units for the 105 mm test system were made.

M. Shirazi

V. Photo Detection Electronics

A preliminary design of the PMT terminal connections and associated differential amplifier was made, but not yet bench tested.

J. deMontlivault

Associated with all phases of the above work: B. H. McCormick, J. N. Snyder

PART V

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of October, two new routines were added to the Illiac Library.

V 18 - 329 Reciprocal Gamma Function for Complex Argument (DOI or SADOI). Given a complex argument Z, with $-1 \leq \text{Re}(Z) = X < 1$ and $-1 \leq \text{Im}(Z) = Y < 1$, this subroutine computes

$$\frac{1}{4} \cdot \frac{1}{\Gamma(Z)} = \sum_{i=1}^{20} C_i Z^i.$$

(John Ehrman)

K 18 - 330 Least Squares Fit of a Lorentz Function to a Set of Experimental Points (SADOI only). This routine fits a set of experimental points with the function

$$f(X) = A + \frac{B}{1 + \left(\frac{X-D}{C}\right)^2} = A + \frac{BC^2}{C^2 + (X-D)^2} .$$

A is the level of the background, B is the height of the peak above background, C is half the full width at half the height of the peak, and D is that value of X for which f attains its peak value.

Optimum values of the parameters A, B, C, and D are found by minimizing the sum of the residuals R:

$$R = \sum_{i=1}^{N} \left[Y_i - f(X_i)\right]^2 W_i,$$

where

N is the number of experimental points, $4 \leq N \leq 205$:,

X_i is the X-coordinate of the ith experimental point,

Y_i is the Y-coordinate of the ith experimental point,

W_i is the weight associated with the ith point.

The quantities W_i may be:

1) $W_i = (1/N)$ for all i,

2) $W_i = (1/N)\, Z_i$

3) $W_i = (1/N)\sqrt{Z_i}$

where Z_i are specified by the user. The third alternative provides for the weighting of an experimental point by the square root of the number of observations or counts at that X_i.

(John Ehrman)

Illiac Usage

During the month of October, specifications were presented for 27 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2066. Numbers followed by T are for theses.

2066 US Navy Personnel Research. Relationships Among Career Motivation Factors. In 1956 a large sample of Navy recruits was selected for a longitudinal study of career motivation. An instrument consisting of 65 items designed to measure attitudes toward the Navy was administered to the recruits as well as to other control groups. At time intervals of about six months, these groups were re-tested to detect any changes. Each of these sets of data were factor analyzed using Illiac.

It is now proposed to make factor comparisons across eight groups of factors. These data are somewhat unusual, for it is not often that studies can be made of the same persons over such a long period of time. In addition, a procedure for comparing factors called indices of relationship was developed recently by Professor Henry Kaiser. It is desired to investigate Kaiser's method using the eight sets of Navy Career Motivation data. The procedure has not yet been used on empirical data. Thus, the study will be both of substantive as well as methodological interest.

2067 Civil Engineering. Underground Structural Response. This research program is concerned with the study of response of underground structures to nuclear explosions. The problem involves the study of propagation of stress waves through non-linear solid media in a 3-dimensional half-space, as well as the interaction of a buried underground structure and the surrounding earth mass as a result of a blast or shock input.

The major portion of the time required on the Illiac will be used for checking and testing parts of a program which may eventually have to be adapted for use on Illiac II because of speed and storage requirements of the problem.

2068T Physics. Superconducting Energy Gap Interpolation. The critical fields of superconducting tin, indium, and mercury have been measured to high precision from the critical temperature to 0.30° Kelvin. Theoretical predictions of the superconducting critical field curve, based on the Bardeen-Cooper-Schriebber model, have been tabulated at discrete temperatures. For detailed comparison of experiment with theory, it is necessary to know critical fields at temperatures between the published values. The Illiac will be used to find the critical fields at these intermediate temperatures by interpolation.

2069 Digital Computer Laboratory. Rounding Error in Matrix Process. The aim of this program is to study the rounding errors occuring in the iterative process

$$\vec{M}_{n+1} = A\vec{M}_n + \vec{c}.$$

Given A, $\vec{c}$, $\vec{M}_0$, the machine computes first N_1 iterations without printing anything, then N_2 iterations with the printing of $\vec{M}_n$ and $\vec{M}_n - \vec{M}_{n-1}$.

2070 Elementary Education. Fluency vs. Process. Illinois studies in inquiry training have involved conducting several hundred tape recorded physics problem solving sessions using inquiry trained and non-trained elementary school children. In order to assess the effects of training on the problem solving procedure, success intercorrelations among the reference and criterion measures are necessary. Computations of means and standard deviations of 110 variables is necessary.

2071 Institute of Communications Research. Connotative-Denotative Measurement. The semantic differential is a measure of connotative meaning, whereas

standard psycho-physical tests measure denotative meaning. In this study a special form of the semantic differential is used which approximates psycho-physical techniques. This is compared with the standard semantic differential using the same scales and concepts. It is hypothesized that the denotative differential will give rise to more factors than the three usually found in the standard form, and that the differences between ratings on the two forms will be an indication of a quantitative measure of denotative meaning.

There are three orders each of the two forms, with 20 subjects in each of the six groups. Each subject made a total of 240 judgments. Means for each of the 240 items will be calculated and compared for each of the six groups. Then centroid factor analyses and rotations will be made over the means for each of the groups.

2072 Astronomy. Models for Outer Envelopes of Red Giants. The purpose of this program is the numerical integration of the differential equations describing the outer envelopes of red giant stars. The results will be used jointly with the results of program 1896 for the integration of red giant central cores.

The four ordinary simultaneous differential equations are:

$$\left(\begin{array}{l} \dfrac{dP}{dr} = -\rho \dfrac{GM_r}{r^2} \\[2ex] \dfrac{dM_r}{dr} = 4\pi r^2 \rho \\[2ex] \dfrac{dL_r}{dr} = 4\pi r^2 \rho \epsilon \\[2ex] \dfrac{dT}{dr}, \text{ which depends on the mode of energy transport through the} \end{array}\right.$$

material layers; either radiation, or convection, or both radiation and convection combined.

P, T, ρ and ϵ are the pressure, temperature, density and nuclear energy production per unit mass at a distance r from the center.

M_r and L_r represent the mass and luminosity within a sphere of radius r.

In order to solve this system of equations one needs three auxiliary relations; the equation of state, the equation of the absorption coefficient and the equation of nuclear energy generation, of the form:

$$P = P(\rho, T, X, Y, Z)$$
$$K = K(\rho, T, X, Y, Z)$$
$$\epsilon = \epsilon(\rho, T, X, Y, Z)$$

where X, Y, Z are respectively the hydrogen, helium and heavier element relative abundance by mass.

Boundary conditions at the surface of the star are chosen as starting values and the integration proceeds inwards. It is stopped when $L_r \longrightarrow o$, i. e., when the energy supply runs out.

The large range in values of the variables and the complexity of the algebra make it very useful to use floating decimal arithmetic. The integration routine FA2 is used.

A number of possibilities for the description of the convective regions and the effectiveness of the convective energy transport will be investigated for different chemical compositions (various X, Y, Z).

2073 Aeronautical and Astronautical Engineering. Solution of "Similar" Equations. A set of similar equations:

$$f'' + ff'' = f'^2 - 1 - a(1 - g^2) - b(1 - \theta)$$
$$g'' + fg' = 0$$
$$\theta'' + d(f\theta') = c(g^2)'''$$

with Boundary Conditions:

$$f(0) = f'(0) = g(0) = \theta(0) = 0$$
$$f'(\infty) = g(\infty) = \theta(\infty) = 1$$

is to be solved using step-by-step integration (e. g., Runge-Kutta method). Initial values are assumed and correct values are obtained by interpolation.

2074 Aeronautical and Astronautical Engineering. Solution of Blasius Equation. Blasius Equation:

$$ff'' + 2f''' = 0$$

with Boundary Conditions:

$$f(0) = f'(0) = 0$$
$$f'(\infty) = 1$$

is to be solved.

Taylor's series and/or Library Subroutine F1 (f" (0) assumed) will be used for the integration and the correct f" (0) found by interpolation.

2075 Mechanical Engineering. Compressible Turbulent Jet-Mixing. This is essentially an extension of the jet mixing problem dealt with in problem number 1215. The present part considers the effect of finite wake velocity on heat and momentum transfers within the wake flow. Calculations to be performed by Illiac include the evaluation and tabulation of the following integrals:

$$I_1 = I_1 \left(\eta, C_a^2, \frac{T_{02}}{T_{01}}\right) = (1 - C_a^2) \int_{-\infty}^{\eta} \frac{\varphi}{\Lambda - C_a^2 \varphi^2} \, d\eta$$

$$I_2 = I_2 \left(\eta, C_a^2, \frac{T_{02}}{T_{01}}\right) = (1 - C_a^2) \int_{-\infty}^{\eta} \frac{\varphi}{\Lambda - C_a^2 \varphi^2} \, d\eta$$

$$I_3 = I_3 \left(\eta, C_a^2, \frac{T_{02}}{T_{01}}\right) = (1 - C_a^2) \int_{-\infty}^{\eta} \frac{\Lambda \varphi}{\Lambda - C_a^2 \varphi^2} \, d\eta$$

where $$\varphi = \varphi_0 + (1 - \varphi_0) \frac{1}{\sqrt{\pi}} \int_{-\infty}^{\eta} e^{-\eta^2} \, d\eta$$

and $$\Lambda = \frac{T_{02}}{T_{01}} + \left(1 - \frac{T_{02}}{T_{01}}\right) \frac{\varphi - \varphi_0}{1 - \varphi_0}$$ φ_0, $\frac{T_{02}}{T_{01}}$ and C_a^2 being parameters.

Floating decimal calculations will be employed throughout.

2076 Chemistry. Solution of Reciprocal Rate Equations for Enzyme Reactions. Reciprocal rate equations have been derived for model enzyme reactions involving two substrates. The data obtained from these solutions will be used to correlate with the experimental data obtained with the enzyme D-ala-D-ala synthetase.

2077 Chemistry. Time Dependent Collision Study. A solution of the time dependent Schrodinger equation for a wave packet will be attempted using Runge-Kutta methods. A simple two dimensional problem will be studied first to test speed and accuracy of the method.

2078 Psychology. Relationships between Factored Electro-Encephologram Dimensions and Factored Personality Dimensions. Eighty subjects have been tested on 150 personality variables and 30 Electro-Encephologram variables. Both sets of variables will be factor analyzed independently and the correlations between the two sets of factors finally determined. This study is the first one in a series of researches in which personality factors will be related to various types of extraneous criterion dimensions. It is, at the same time, the first attempt to use exclusively factor-analytic methods in investigating such relationships.

2079 Psychology. Factor Analysis of Derived Variables, the Mathematical Derivation of which is Known. Derived variables (such as: $\frac{a+b}{c \cdot d}$, etc.) are of special psychological importance in factor-analytic personality research; however, the effects of including such derived variables together with the primitive variables a, b, etc. into the same score matrix are mathematically not fully understood.

In this research a matrix of four orthogonal and two slightly correlated factor scores will be generated and a set of primitive variables computed therefrom--their factor structure being fixed a priori. From some of these primitive variables a new set of derived variables will be computed, and both sets of variables will then be factor analyzed together. This type of analysis will show whether "new", i. e., more than the original six, factors emerge after including the derived variables into the analysis, and in which way the particular derivation equations used might distort the loading pattern.

2080 Digital Computer Laboratory. Partition Function for Two Interacting Particles-II. The quantum mechanical partition function for a system of two interacting particles in a box is computed. Boltzmann statistics are used (i. e., symmetry conditions on the wave function are ignored) and a two-dimensional coordinate system is used. The interaction potential is a square well with a hard core. The method is based on the numerical evaluation of path integrals (conditional Wiener integral) for the system. Monte Carlo sampling is used in this evaluation. This program is a modification of an earlier program, "Partition Function for Two Interacting Particles", to allow for a wider variation of parameters.

2081 Electrical Engineering. Calculation of the Optimum Number of Stages of Electronic Network for a Given Figure of Merit. The figure of merit of an amplifier tube places a limitation on the gain/bandwidth product. When several stages are cascaded, the bandwidth must be increased, with a subsequent loss of gain per stage, so that the overall bandwidth is constant.

In this problem Illiac will be used to determine the optimum number of stages for a given tube and bandwidth.

2082 Coordinated Science Laboratory. Constants for Random Deviate Generator. A fast routine for the generation of normal random deviates is desired, using random numbers uniformly distributed on the interval (-1, 1). One way to do this is to approximate the inverse of the Normal Probability Integral, $[\text{N.P.I.}]^{-1}(x)=y$; where

$$x = \text{N.P.I.}(y) = \sqrt{\frac{2}{\pi}} \int_0^Y e^{-t^2/2}\, dt \qquad (1)$$

If x is uniformly distributed on (-1, 1), y will be a normal deviate on $(-\infty, \infty)$. The approximation will be accomplished by making a piecewise linear fit to $[\text{N.P.I.}]^{-1}$, so that the generator will be simply

$$y = y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i}(x - x_i); \quad i = 0, 1, \ldots\ldots, N-1 \qquad (2)$$
$$y_0 = x_0 = 0$$

The 2N+1 x_i will be evenly spaced on (-1, 1), and $N = 2^q$, q an integer, will be chosen so the division in (2) above is simply a left shift, with the proper y_i chosen by planting an address formed from the first q bits of the uniform random number x. This program calculates the y_i given N = 8, 16, 32, such that the integrated squared error is a minimum:

$$I = \min_{\{y_i\}} \sum_{i=0}^{N-1} \int_{y_i}^{y_{i+1}} \left[\sqrt{\frac{2}{\pi}} \int_0^y e^{-t^2/2}\, dt - x_i - \frac{x_{i+1}-x_i}{y_{i+1}-y_i}(y-y_i)\right]^2 dy$$

Minimization is accomplished by the Method of Steepest Descents (H5), and integration by Gauss' Quadrature (E5).

2083 Electrical Engineering. Large Antenna Arrays with Randomly Spaced Elements. Large antenna arrays for radio astronomy research usually require an extremely large number of elements. It is belived that by using a randomization of the element spacings, a major fraction of these elements can be eliminated.

This investigation involves the following three stages in computation: first, determine the distribution function at each observation angle of the diffraction pattern; secondly, determine the distribution of the total power gain; thirdly, demonstrate by Monte Carlo Method the feasibility of such a technique.

For the first computation, the distribution function is given by:

$$P(r) = \int_0^r \int_0^{2\pi} \frac{R}{2\pi \sigma_1 \sigma_2} \exp\left\{ - \frac{(R \cos \theta - m)^2}{2 \sigma_1^2} - \frac{(R\, q \sin \theta)^2}{2\sigma_1^2} \right\} d\,\theta\, d\,R$$

where the parameters m, σ_1, σ_2 are functions of the angle of observation θ, namely

$$m(y) = R_e \int_0^a f\,(x)\, e^{\,j2\pi xy} dx$$

$$\sigma_1^2(y) = \frac{1}{r}\left\{ a \int_0^a |f(x)|^2 \cos^2 2\pi xy\, dx - m^2\,(y) \right\}$$

$$\sigma_2^2(y) = \frac{a}{r} \int_0^a |f(x)|^2 \sin^2 2\pi xy\, dx$$

$y = \text{Sin}\ \theta$

$f(x)$ = a given weighting function

n = number of elements

a = length of the antenna in wavelengths

2084T Mechanical Engineering. Two Phase Nozzle Flow. The one dimensional two phase flow equations for a gas-solid suspension through a nozzle of arbitrary area distribution neglecting wall heating and wall friction are:

$$(1)\quad \frac{dA}{A} + \frac{du}{u} + \frac{dp}{p} = \frac{dt}{t}$$

$$(2)\quad \frac{dt}{dx} + \frac{2udu}{dx} + m_p \frac{u}{u_p} \frac{c_p}{c} \frac{dt_p}{dx} + m_p \frac{u}{u_p} 2u_p \frac{du_p}{dx} = 0$$

$$(3)\quad u_p \frac{du_p}{dx} = E(u-u_p)$$

(4) $\frac{1}{p} \frac{dp}{dx} + \frac{c}{R} \frac{2u}{t} \frac{du}{dx} + m_p \frac{u}{u_p} \frac{c}{R} \frac{2u_p}{t} \frac{du_p}{dx} = 0$

(5) $-u_p \frac{dt_p}{dx} = B(t_p - t)$

(6) $\frac{dA}{dy} = f(x)$

if $\frac{dA}{dx} = \left[1 - \frac{c_e}{R} (1 + m_p \frac{b}{a})\right] \left[1 - \frac{c}{c_e} a^2 x^2)^{- \frac{c_e}{R} (1 + m_p \frac{b}{a}) 778.16}\right]$

(7) $\left[-2 \frac{c}{c_e} a\right] - \frac{1}{ax^2} (1 - \frac{c}{c_e} a^2 x^2)^{1 - \frac{c_e}{R} (1 + m_p \frac{b}{a}) 778.16}$

then $u = ax$ and $u_p = bx$ this is known as the linear case.

where	A	is area
	p	is pressure
	u	is gas velocity
	u_p	is particle velocity
	t	is gas temperature
	t_p	is particle temperature
	m_p	is lb. solid per lb. gas
	E	is drag parameter
	c	is specific heat at constant pressure of gas
	c_p	is specific heat of solid particles
	R	is gas constant

All of the above quantities are made dimensionless.

The boundary conditions are

At $x = 0$ $t = 1$, $p = 1$, $t_p = 1$, $u = 0$, $u_p = 0$

These equations have been solved on the IBM 650. However, another boundary condition must be added at the throat (section of minimum area) which increases the difficulty of the solution and demands the use of an iterative

method. For these reasons it seems desirable to attempt the solution on the Illiac.

2085 Digital Computer Laboratory. Finding the Minimal Cost Covering. Consider the "black points" of a photograph such as one taken of a bubble chamber. Consider a set of "templates" which might be placed upon the photograph so as to cover some of the black points. Let there be assigned to each template a price which must be "paid" if the template is used.

The problem is to find the cheapest way of placing templates on the picture so that every black spot is covered.

In essence, one is seeking an optimum encoding of the information on a photograph.

2086 Bureau of Educational Research. Comparison of Reliability Measures. In a study aiming at a parametric comparison of a number of different (internal consistency) reliability measures it is planned to use Illiac to generate hypothetica tests subject to certain specifications and examine empirically how these different internal consistency measures vary with test and item parameters.

A similar program which was written for an earlier study utilizing more stringent assumptions in regard to homogeneity of the item universe (with respect to item difficulty and inter-item covariance) is already in existence (problem number 1345).

In the present study, it is planned to relieve some of these restrictions, i. e., the item universe will not be partitioned into a number of strata, either with respect to item difficulty, inter-item covariance, or both.

Specifically, the new routine will have to have the following features:

(1) Parameters of the universe to be sampled from will be stored.

(2) A sampling plan will be fed into Illiac, according to which hypothetical tests will be assembled with items from the universe.

(3) Variance and covariance characteristics of the sample tests will then be used for a comparison of a number of different reliability indices.

2087 Physics. Integration of Characteristic Annealing Function. In order to study the kinetics of thermally activated processes, certain integrals are needed. These will be calculated by using this program.

The concentration of some arrangements in a sample can be measured by means of a property P, which is believed to be proportional to the concentration. As the arrangements decay at constant temperature T, P(t) decreases with time t and can be written as

$$P(t) = \int_0^{\infty} p(\epsilon)\, d\epsilon$$

where $p(\epsilon)$ is the density of the activation energy spectrum, ϵ the activation energy.

The density function depends on the treatment of the sample and the initial activation energy spectrum in the following way

$$p(\epsilon) = p_o(\epsilon)\; f(\epsilon) \quad \Theta\,(\epsilon, T, t)$$

$p_o(\epsilon)$ is the initial density function, the value of which is to be calculated.

$f(\epsilon)$ is a monotonically increasing function of ϵ which describes the degree of completion of the distribution of annealing processes due to all previous annealing. $f(\epsilon) = 0$ for $\epsilon = 0$, $f(\epsilon) = 1$ for $\epsilon = 1$. $\Theta\,(\epsilon, T, t)$ is the same sort of function as $f(\epsilon)$ and expresses the degree of completion of the process having activation energy ϵ when the sample is annealed for a time t and constant temperature T.

2088 Mining and Metallurgical Engineering. Computation of Function Tables. This program will compute and tabulate

$$d = \frac{.97483}{\sin(16.77^{\circ} + 1.437\ell^{\circ})}$$

between $\ell = 0.1$ to $\ell = 40.0$ in increments of 0.1 and will also compute and tabulate

$$\log_{10} d \text{ and } \frac{1}{d^2}$$

for the same values of ℓ.

2089 Chemistry. VCl_4 Energy Levels. The research problem is the same as that described under 650 problem number 211'; that is, the calculation of vibrational energy levels for certain states of VCl_4. The WKB calculations done on the 650 yielded approximate values for many levels. It is now desired to improve several of these values, especially the lowest, by actual solution of the Schroedinger equation. This requires modification of the programs developed under problem number 1043, which are, in turn, modifications of library routine F4.

2090 Electrical Engineering. Non-Linear Oscillating Systems.

$$\frac{d^2y}{d\tau^2} = \frac{y^2 - y + \gamma}{1 - y} \quad \text{and} \quad \frac{d^2\theta}{d\tau^2} = (\cos\theta - \lambda)\sin\theta$$

are the differential equations of two non-linear oscillating systems which behave very critically with respect to the parameters γ and λ. A computer solution is proposed to appreciate fully the difficulties involved in the solution of non-linear differential equations.

2091 Physics. Kinematics of Two Body Collisions with the Production of Two Particles. The physical situation is the striking of one particle by another, causing two new particles to be emitted.

Knowing the masses of all four particles and the momentum of the incident particle, the problem is to calculate the directions and the momentum of the particles produced.

2092 Chemistry. Construction of Hybrid Orbitals. An attempt is being made to explain the apparent deviation from tetrahedral bonding in CH_2X_2 type molecules where X is a halogen atom. The calculations involve diagonalizing overlap matricies formed from a trial set of carbon hybrid orbitals with the ligands. By proper transformations a linear combination of trial functions is obtained and represents the best hybrid orbitals. From these best hybrid orbitals the directivity of the carbon bonding is obtained. This can then be compared to experimentally determined bond angles very accurately determined by microwave spectroscopy.

Table I shows the distribution of Illiac machine time for the month of October.

TABLE I

	Hrs:Min	
Scheduled Maintenance	67:18	
Unscheduled Maintenance	12:31	
Drum Engineering	8:06	
Leapfrog	6:40	
Library Development	4:56	
Classes	4:55	
Instruction	:02	
Wasted	:09	
		104:37

Use by Departments

Aeronautical Engineering	9:36
Agricultural Economics	39:22
Agronomy (ARS-46-15-15-317)	:27
Agronomy (0015-15-306)	:06
Animal Science	2:05
Astronomy (NSF-G-14834)	2:21
Bureau of Economic and Business Research	1:58
Bureau of Educational Research	:16
Chemistry (NSFG-5907)	22:58
Chemistry	62:09
Civil Engineering (NSF-G6572)	:04
Civil Engineering (HIGHWAY BRIDGE IMPACT)	8:55
Civil Engineering (DA-104)	1:30
Civil Engineering	56:22
College of Medicine	4:53
Coordinated Science Lab. (DA-36-039-SC56695)	71:05
Dairy Science	1:20
Digital Computer Laboratory (NSF GRANT 9503)	1:16
Digital Computer Laboratory (AEC AT(11-1)-415)	:58
Digital Computer Laboratory (US TR AEC-1018)	3:16
Digital Computer Laboratory (NONR 1834(27))	67:29
Digital Computer Laboratory	1:15
Economics (NSFG 7056)	:41
Education	7:19
Electrical Engineering (NONR 1834(22))	2:40
Electrical Engineering (NASA-NSG24-59)	9:09
Electrical Engineering (AF7043)	11:26
Electrical Engineering (NOBSR 64723)	1:51
Electrical Engineering (NSFG 19005)	2:57
Electrical Engineering	5:44
Finance (IHR-71)	:07
Food Technology (50-343)	11:34
Geological Survey	:05
Geology	:36
Horticulture (00 15 65 330 38)	1:22
Illinois State Normal University	:40

Institute of Communications Research (44-28-20-378)	5:48
Institute of Communications Research (USPHM-3941)	5:18
Institute of Communications Research	5:03
Institute of Labor and Industrial Relations	1:04
Mathematics	:04
Mechanical Engineering	15:24
Mining and Metallurgical Engineering (TRUS AF 6770)	:17
Mining and Metallurgical Engineering	6:02
Music	2:26
Natural History Survey	4:43
Office of Instructional Television (OE 7-11-107.00)	:59
Office of Instructional Television	:09
Physical Education	6:51
Physics (AF 49(638)661)	:44
Physics (NONR 1834(05)A)	2:26
Physics	28:11
Psychology (1715)	:41
Psychology (AF 49(638)371)	9:03
Psychology (MD 2060)	:32
Psychology (AF 41-657-279)	1:04
Psychology	65:01
Sociology	9:59
State Water Survey (NSFG 6572)	3:47
State Water Survey (DA-36-039-SC75055)	10:24
Theoretical and Applied Mechanics (NOBS 72069)	1:03
Theoretical and Applied Mechanics (DA-11-070-508 ORD)	32:36
Theoretical and Applied Mechanics (DA-01-021 ORD 11878)	3:38
United States Navy	1:54
	640:23
	745:00

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period

in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the possibility of a failure during any given interval of running time.

TABLE II

Punch		2
Reader		3
Memory		1
Control		2
Input-Output		2
Drum		9
Unknown		3
	Total	22

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/1/61	23:59	:01	:00	1	(1) Punch #1 jammed.	:00	:42	0
10/2/61	21:51	:00	2:09	0		:00	:54	0
10/3/61	21:29	:00	2:31	0		:00	:44	0
10/4/61	20:44	:30	2:46	1	(1) Memory failure, reason unknown.	:00	:17	0
10/5/61	20:18	:02	3:40	1	(1) Leapfrog failure, input-output, reason not known.	:00	:33	1
10/6/61	21:05	:37	2:18	2	(1) Reader failure, reader "B". (2) Drum failure.	:00	:00	0
10/7/61	22:37	1:23	:00	3	(1) Drum failure. (2) Drum failure. (3) Drum failure.	:00	:00	0
10/8/61	23:34	:26		1	(1) Reader failure, reader "G".	:00	:15	0
10/9/61	22:58	:02	1:00	2	(1) Unknown. (2) Unknown.	:00	:09	0
10/10/61	20:30	:00	3:30	0		:00	:12	0
10/11/61	20:23	:37	3:00	1	(1) Drum failure.	:00	:00	0
10/12/61	20:40	:00	3:20	0		:00	:00	0
10/13/61	20:56	:34	2:30	1	(1) Drum failure.	:00	:20	0
10/14/61	22:31	1:29	:00	2	(1) Punch error, punch #1. (2) Control error.	:00	:00	0
10/15/61	21:45	2:15	:00	1	(1) Control error.	:00	:00	0
10/16/61	21:25	:00	2:35	0		:00	:07	0
10/17/61	20:23	:00	3:37	0		:00	:00	0
10/18/61	21:46	:14	2:00	1	(1) Reader error, reader "B".	:00	:00	0
10/19/61	17:45	2:13	4:02	1	(1) Drum failure.	:00	:06	0
10/20/61	19:55	1:25	2:40	1	(1) Drum failure.	:00	:07	0
10/21/61	24:00	:00	:00	0		:00	:00	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/22/61	24:00	:00	:00	0		:00	:00	0
10/23/61	20:25	:00	33:35	0		:00	:22	0
10/24/61	20:47	:00	3:13	0		:00	:05	0
10/25/61	20:32	:00	3:28	0		:00	:00	0
10/26/61	19:55	:35	3:30	1	(1) Drum failure.	:00	:07	0
10/27/61	20:48	:42	2:30	1	(1) Input-output failure.	:00	:00	0
10/28/61	25:00	:00	:00	0		:00	:07	0
10/29/61	23:47	:13	:00	1	(1) Unknown.	:00	:23	0
10/30/61	19:41	:00	4:19	0		:00	:29	0
10/31/61	21:28	:00	2:32	0		:00	:01	0
Total	666:57	13:18	64:45	22		:00	6:02	1

PART VI

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New International Business Machines 650 Codes

During the month of October, four new routines were added to the International Business Machines 650 Library.

K11' - 81' (ATHOS) Five/Card Loader.

(J. Flenner)

X12' - 82' (ATHOS) Five/Card Condenser.

(C. Wilmot)

P10' - 83' (ATHOS) Drum Dump.

(J. Flenner)

The above three programs are subroutines compatible with the Digital Computer Laboratory 650 Executive System (ATHOS). These subroutines are sufficiently general that they have a utility apart from the system itself. They can be used for program input, program diagnosis and program condensation. The results of these operations are compatible with the various stages of program treatment by the ATHOS system.

K11' - 84' Analysis of Variance and Single Degree of Freedom Analysis for Factorial Experiments with 1, 2, 3 or 4 Factors as Successive Splits in a Split Plot Randomized Complete Block Design. This program computes and prints the treatment means, analysis of variance tables, and single degree of freedom analysis for factorial experiments with 1, 2, 3 or 4 factors as successive splits in a split plot randomized complete block design. The levels of factor A constitute main plots which are arranged in a randomized block; the levels of factor B are sub plots within the main plots; the levels of factor C are sub-sub plots within

the sub plots; the levels of factor D are sub-sub-sub plots within the sub-sub plots.

A maximum of 9 sets of observations in 5 digit data fields can be analyzed per problem. A 10th data field is available for use in conversions, but analysis of variance may be obtained for the first 9 data fields only. Single degree of freedom analysis is optional for each of the first 9 data fields.

There are 13 conversions available, if it is desirable to convert the original data to another form before performing the analysis of variance.

All parameters, coefficients for single degree of freedom analysis, and data are read in as fixed point numbers and changed to floating point for computation. All output is printed on-line on the 407 in fixed point form.

(S. G. Carmer)

International Business Machines 650 Usage

During the month of October, specifications were presented for 11 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 323'. Numbers followed by T are for theses.

323' Agronomy. Study of High Oil Corn. This problem involves the evaluation of performances of 50 high oil corn hybrids with respect to yield, lodging, oil content and disease resistances. These trials, four in number, utilize semi-balanced lattice square designs. The IBM 650 will be used in computing the analysis of variances for these trials.

324' Food Technology. Corn Quality Measurements. The time and temperature of cooking whole kernel corn prior to freezing affects the amount of enzyme retention. Several cooking times and storing times were studied in relation to enzyme activity. Both enzyme and organoleptic measurements were made.

The STAMP routine will be used to determine the effects of blanch time, storage temperature, and time of the corn on the amount of enzyme retention and organoleptic measurements.

325' Chemistry. Schottky Barrier Maximum. Illiac problem number 1414, an investigation into the theory of thermionic emission in the presence of a weak applied field and the periodic deviations from the Schottky line, has yielded some very interesting curves for transmission coefficient vs. energy for a potential barrier of the form:

$$V(r) = \begin{cases} -\frac{1}{2r} + \frac{\zeta}{4r^2} - fr, \text{ for } r > r_s \\ -E_a, \text{ for } r \leq r_s \end{cases}$$

where r_s is the smallest solution of $-E_a = -\frac{1}{2r} + \frac{\zeta}{4r^2} - fr$.

It is now desired to relate the transmission coefficient curve with the barrier height for various values of f. It is therefore proposed to use the IBM 650 to find these barrier heights. This amounts to finding the maximum of V(r), a simple algebraic process.

326'T Mining and Metallurgical Engineering. Surface Energy of Solids. It has been proposed that the hardness H of a rock material can be calculated from experimental data obtained by the method of damped oscillations. The apparatus used is a pendulum which is supported on the material to be tested by two sharp points. Thus, with a soft material the points will penetrate the sample further and the pendulum will be damped more quickly than if the test sample is hard. The pendulum is initially deflected to an amplitude, Ao, released and allowed to oscillate. At various times t, the amplitudes A are recorded. These values are related to hardness H as:

$$H = \frac{t}{\ln\frac{Ao}{A}}$$

where H = hardness

t = time

A = experimentally determined amplitude as a function of time

Ao = initial deflection of pendulum.

This equation can be written in the form:

$$\ln A = \ln Ao - (1/H)\,t$$

The various values of lnA and t can be plotted from which the best slope H (hardness) can be determined. The parameter H (hardness) is the one which is determined from the experimental procedure. Use of the IBM 650, using the least squares routine to determine the "best" linear fit, will greatly reduce the time required to analyze the many sets of data. The library routine of the method of least squares (650 library routine K7'-68') has been modified only insofar as to incorporate the natural logarithm routine (650 library routine S1'-8).

327' Bureau of Community Planning. In this research problem, we are attempting to develop a traffic model with which to estimate intercommunity travel. The communities involved are within a 14 county area in East Central Illinois. Trips are divided into vehicle and person trips and each of these are further subdivided into seven trip purpose categories. Various independent variables designed to measure the ability of each community to produce or attract trips (such as population, auto registration, employment, retail sales, etc.) are to be correlated with the known trips that occurred in 1958. Simple correlations between each independent variable with several transformations are to be made in order to provide information as to the potential value of each variable. Following selection of the most likely variable for each type and purpose of trip, multiple correlations are to be run between the dependent variable and 2, 3 and 4 selected independent variables. From these computer results, the final models will be derived for each trip type and purpose and for an aggregate or all purpose category.

328'T Mechanical Engineering. Base Pressure Studies. The following data are obtained from experiments:

$$p_i,\ po_{gage},\ \text{zero},\ p_{atm},\ p_\infty$$

The following quantities are to be calculated:

$$p_{i\ abs} = p_{atm} - (p_i - \text{zero})$$

$$p_{\infty\ abs} = p_{atm} - (p_\infty - \text{zero})$$

$$p_{o\ abs} = p_{atm} + p_{o\ gage}$$

$$\text{Mach No} = \sqrt{5\left(\frac{p_{o\ abs}}{p_{\infty\ abs}}\right)^{\frac{k-1}{k}} - 5} \qquad k = 1.4 \text{ for air}$$

$$c_p = \left[\left\{(p_{i\ abs}/p_{\infty\ abs}) - 1\right\} \Big/ .7\ M^2\right]$$

Basically, the problem involved is that of taking raw pressure data from the blow-down wind-tunnel and converting these pressures to pressure coefficients.

Presently, a parabolic body of revolution is being investigated in the wind-tunnel and an attempt to determine the pressure distribution over this body at transonic speeds is being made.

This program is input-output dominated and should run at full print speed.

329' Digital Computer Laboratory. A Study of Functional Integrals. This calculation involves the evaluation of series of the form

$$S = \sum_{k=1}^{\infty} e^{-\alpha k^2}$$

for certain values of α. This is being used to check results obtained by an Illiac program (1944) and to evaluate certain functional integrals.

330' Mechanical Engineering. Fundamental Mechanism of Tool Wear. The research program for the determination of the temperature distribution over a tool-chip interface from measured flank surface temperature involves the solution of a set of linear simultaneous equations of the form

$$\sum_{i=1}^{n} d_{ij}\,\Theta_i = f_j \qquad (j = 1, 2, \ldots.\ n)$$

It was found that this set of equations encountered is ill-conditioned.

The nature of this problem is to solve the ill-conditioned, algebraic, linear, simultaneous equations by an iterative procedure. It is based on an approximate modification of the coefficient matrix and thereby removes or reduces the ill-conditioned characteristics of the equations.

Consider an ill-conditioned matrix,

$$|A| = \begin{vmatrix} a_{11} & - & - & - & - & a_{1n} \\ & \ddots & & & & \\ & & \ddots & & & \\ & & & \ddots & & \\ a_{n1} & & & & \ddots & a_{nn} \end{vmatrix}$$

The leading diagonal is modified by adding the diagonal matrix $|\alpha I|$ and $|A|$, $|I|$ being the unit matrix. The α's are to be selected so that in any equation the absolute value of the coefficients along the leading diagonal is greater than the sum of the absolute values of all the remaining coefficients in that equation.

$$|A + \alpha I| \quad X = [f] + \alpha X \; \ldots\ldots$$

To solve this equation, an iterative procedure is used as follows

$$|A + \alpha I| \quad \sqsubset\!\sqsupset^{(m)} = \begin{cases} f & \text{for } m = 1 \\ \alpha \sqsubset\!\sqsupset^{(m-1)} & \text{for } m > 1 \end{cases}$$

331'T Theoretical and Applied Mechanics. Stress Distribution in Thick Walled Cylinders. This problem involves the solution of three mathematical expressions which give the stress distribution in the wall of a thick walled cylinder. Also included are three expressions which give the strains throughout the cylinder.

The following definitions apply:

β - ratio of strain in the z direction to the effective strain in the member.

K - ratio of effective strain to a material constant, ϵ_0.

y - ratio of distance from the t axis to the point where the stress is desired to the inside radius.

Δ_y - increment in y.

σ_r - the radial stress at the distance of y from the z axis.

σ_0 - a material constant.

σ_θ - the tangential stress at the distance of y from the z axis.

σ_z - the longitudinal stress.

The following expressions will be solved on the IBM 650:

$$\frac{\Delta\sigma_r}{\sigma_0} = \frac{2}{\sqrt{3}} \frac{1}{y} \frac{1-\beta^2}{\sqrt{1-\beta^2+\beta^2 y^4}} \text{ arc sinh } \frac{K}{y^2} \sqrt{1-\beta^2+\beta^2 y^4} \; \Delta y$$

$$\frac{\sigma_\theta}{\sigma_0} = \frac{\sigma_r}{\sigma_0} + \frac{\Delta\sigma_r}{\sigma_0} \frac{y}{\Delta y}$$

$$\frac{\sigma_z}{\sigma_0} = \frac{\beta y^2}{\sqrt{1-\beta^2+\beta^2 y^4}} \text{ arc sinh } \frac{K}{y^2} \sqrt{1-\beta^2+\beta^2 y^4} + \frac{1}{2}\left[\frac{\sigma_\theta}{\sigma_0} + \frac{\sigma_r}{\sigma_0}\right]$$

$$\frac{\epsilon_z}{\epsilon_0} = \beta K$$

$$\frac{\epsilon_\theta}{\epsilon_0} = \frac{\sqrt{3}}{2} \frac{K}{y^2} \sqrt{1-\beta^2} - \frac{\beta K}{2}$$

$$\frac{\epsilon_r}{\epsilon_0} = -\frac{\sqrt{3}}{2} \frac{K}{y^2} \sqrt{1-\beta^2} - \frac{\beta K}{2}$$

with the following ranges on the variables:

$0.1 \leq \beta \leq 0.9$

$3 \leq K \leq 140$

$\Delta y = 0.05$

y = either 2.0 or 1.5.

With this information, graphs of the following will be constructed:

$$\frac{\sigma_\theta}{\sigma_0} \text{ vs } \frac{\epsilon_\theta}{\epsilon_0}, \quad \frac{\sigma_z}{\sigma_0} \text{ vs } \frac{\epsilon_z}{\epsilon_0}, \quad \frac{\sigma_r}{\sigma_0} \text{ vs } \frac{\epsilon_r}{\epsilon_0} \quad \text{for } y = 2.0 \text{ and } 1.5$$

with β = 0.1, 0.2, 0.3, ..., 0.9 in each case.

Also, a graph of K vs y will be constructed and perhaps graphs of

$$\frac{\sigma_\theta}{\sigma_0} \text{ vs } \frac{r}{a}, \quad \frac{\sigma_z}{\sigma_0} \text{ vs } \frac{r}{a}, \quad \frac{\sigma_r}{\sigma_0} \text{ vs } \frac{r}{a}.$$

332'T Electrical Engineering. Impedance of Wire Antennas. The problem is formulated by using a variational technique. An approximate solution of the input impedance of the wire antenna is expressed in terms of definite integrals. The integration of these integrals will be performed by the IBM 650 using routine E1'-61.

333' Animal Science. Effect of Breeding, Feeding, and Chronological Age on Pork Quality. This problem involves the analysis of variance of a non-orthogonal matrix. Data collected at the University of Illinois and American Meat Institute Foundation relating to breed, feeding, management, carcass characteristics and palatability measurements will be related to the quality of pork.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of October.

TABLE I'

		Hrs:Min	
Scheduled Engineering		18:54	
Unscheduled Engineering		20:53	
Tape Test		9:35	
Computer Operator		2:12	
Log Summary		1:31	
Library Development		34:31	
Agronomy Library	5:14		
DCL Library	29:10		
SSU Library	:07		
Classes		26:19	
CE 316	:04		
CE 391	4:15		
EE 322	:47		
EE 342	:10		
MATH 195	21:03		
Instruction		:26	
Demonstrations		2:23	
Wasted		47:22	
			164:06

Use by Departments

Agronomy	8:56
Animal Science	16:53
Chemistry	7:43
Civil Engineering	14:51
Electrical Engineering	6:43
Food Technology	3:59

Graduate College		1:17		
Mechanical Engineering		3:35		
Mining and Metallurgical Engineering		1:41		
Physics		3:38		
State Geological Survey		:22		
State Water Survey		7:46		
Statistical Service Unit		107:01		
Agricultural Economics	:41			
Agricultural Extension	7:27			
Bureau of Community Planning	1:06			
Bureau of Educational Res.	2:23			
Bureau of Institutional Res.	2:32			
Bursar's Office	14:02			
Business Office	29:07			
DHIA	45:06			
Education	:25			
Forestry	2:47			
Horticulture	:40			
Physical Education	:15			
Statistical Service Unit	:07			
Student Counseling	:23			
Theoretical and Applied Mechanics		:48		
			185:13	
				349:19

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for October.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

533 card read punch		4
Oil needed	1	
Defective switch	1	
Card jam	1	
Punched incorrectly	1	
727 and 652 tape units and tape control		8
Rewinds improperly	2	
Reads incorrectly	1	
End of tape not recognized	1	
Quiver in take-up reel	1	
Not obeying tape order	2	
Selection lights on control incorrect	1	

653 high speed storage, floating point, index registers		1
False light	1	
650 console and magnetic drum unit		7
Blank or multiple bits	6	
Fuse	1	
407 accounting machine		7
Fuse	2	
Prints incorrectly	3	
Doesn't print at all	1	
Card jam	1	
	TOTAL	27

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
10/2/61	9:55	3:04		3:36	0	
10/3/61	9:49			6:22	1	(1) 407 blew a ground fuse.
10/4/61	15:28		:10	:52	1	(1) 407 blew a ground fuse.
10/5/61	13:28		:15	1:02	1	(1) 533 developed a bad squeak. Oil needed.
10/6/61	10:24		2:29	3:09	3	(1) Multiple bits in pos. 5 of distributor. (2) Blank bits in pos. 1 of program register. (3) Tape unit 1 not rewinding properly.
10/9/61	10:44	3:52		:59	0	
10/10/61	17:03		2:48	:25	1	(1) 533 start switch defective. Replaced.
10/11/61	15:48			:05	3	(1) Multiple bits in pos. 5 of distributor. (2) Lost bit in pos. 3 of program register. (3) Tape unit 3 did not recognize end of tape.
10/12/61	13:09		2:32	:15	2	(1) Tape unit 2 had a quiver in take-up reel. (2) False storage selection lights on 74 orders.
10/13/61	11:46			3:44	0	
10/16/61	4:23	3:56	:31	6:36	1	(1) 407 prints alpha instead of number.
10/17/61	10:16			5:08	0	
10/18/61	15:17			1:21	2	(1) Lost quinary bit in pos. 8 of distributor. (2) 407 printing too soon after a page eject.
10/19/61	11:37		1:18	2:21	4	(1)(2) Tape unit 2 did not receive or obey the 04 order. (3) Tape control had 0, 1 and 3 as indicating last tape selected. (4) 533 fails to punch col. 36 of card.
10/20/61	12:08			2:50	0	
10/23/61	9:31	4:07		1:55	1	(1) 407 prints * at end of each word when on line.
10/24/61	13:12		:45	1:54	2	(1) Tape unit 3 does not go into a low speed rewind as soon as it should. (2) Trouble reading from tape units 2 and 3.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
10/25/61	10:15		1:10	4:05	2	(1) 407 would not print on line or off line. (2) Lost quinary bit in pos. 1 of prog. reg.
10/26/61	15:26			:30	0	
10/27/61	:03		8:53	:08	2	(1) Fuse blew. (2) Card jam in 533 read.
10/30/61	14:23	3:55	:02		1	(1) Had five card jams in 407.
Total	262:10	18:54	20:53	47:22	27	

PART VII

INSTRUCTIONAL USE OF COMPUTERS

From its inception, this Laboratory has offered courses in the direct programming of its computers. Both of the courses offered so far, Mathematics 295, "Introduction to the Use of Digital Computers", and Mathematics 395, "Advanced Programming", have used the computers heavily. Students are assigned actual homework to be done on the machines. This year, a new course, Mathematics 195, "Introduction to Automatic Digital Computing", has been instituted. It is intended that over the next several years this course will be added to the various curricula in the engineering college until it is taken by all undergraduate engineers sometime during their sophomore year. This, in turn, will lead to a direct use of computers as an integral part of the assigned work in upper class engineering courses.

In order to facilitate and encourage such use, new logging and problem specification procedures more suited to these needs than the original research problem specifications and procedures have been instituted.

The information pertinent to such use of the computers will be incorporated in this and future Technical Progress Reports of the Digital Computer Laboratory.

1 Mathematics 195. Problem 1. IBM 650. Table of Powers of Integers. Write a machine language program to compute a table of the floating-point numbers X, X^2, X^3, X^4 for $X = 0\ (1)\ 20$. Follow the same output procedure as used in the demonstration program; the last instruction executed by your program must be 0000008000. Prepare your program deck as described in the handout "Preparing the First Machine Language Problem". No data cards are necessary for this program.

2 Mathematics 195. Problem 2. IBM 650. Free Fall at Equator and Pole. The motion of a body which is dropped (zero initial velocity) and falls under the influence of gravity is described by the equations

$$v = gt \quad ,$$

$$s = 1/2\ gt^2 \ ,$$

where v is the velocity of the body t seconds after being dropped and s is the distance that the body has traveled in this time interval. The values of g at the equator and north pole are:

$$g = 32.086 \text{ ft/sec}^2, \text{ (equator)}$$

$$g = 32.258 \text{ ft/sec}^2, \text{ (north pole)}$$

Write a GAT program to make a table of t, v (equator), s (equator), v (pole), s (pole) for t = 0 (0.1) 2; to represent these five quantities use the GAT variables X1, X2, X3, X4, X5, respectively.

3 Civil Engineering 214. Problem 1. IBM 650. Statistical Analysis. The program is a first attempt to implement the GAT compiler for student's use in an undergraduate course. The GAT source deck to compute the mean, standard deviation, and limits of uncertainty for a set of n concrete cylinder strengths has been prepared. It is hoped that these examples will demonstrate to the students the need for and use of our campus computing facilities.

4 Civil Engineering 316. Problem 1. IBM 650. Following is a copy of the problem involved. These represent the six types of general linear programs that exist. In order to orient the students to the linear programming routines and the 650 installation, it is requested that they produce the data, etc. for these numerical exercises and submit these problems for production runs.

The routine is written so that all of the data cards for all problems in any order can be processed in a single run if the operator so desires.

The mathematical method is the regular simplex technique for linear programming.

(a) Maximization problem with inequalities.

$$x_1 + x_3 \leqslant 2$$

$$-x_1 + x_2 + 3x_3 \leqslant 3$$

$$x_1 + x_2 + 3x_3 = f = \text{maximum}$$

(b) Maximization problem with inequalities; fewer structural variables than restrictions, i. e., no solution in structural variables only is possible.

$$x_1 + 3x_2 \leq 21$$

$$2x_1 + 3x_2 \leq 24$$

$$x_1 + x_2 \leq 10.5$$

$$2x_1 + 4x_2 = f = \text{maximum}$$

(c) Minimization problem with inequalities.

$$x_1 + 2x_2 + 4x_3 \geq 12$$

$$3x_1 + 2x_2 + x_3 \geq 8$$

$$4x_1 + 3x_2 + x_3 = g = \text{minimum.}$$

(d) Minimization and maximization problem with equations. (Two problems).

$$x_1 + x_2 + x_3 + x_4 = 1$$

$$0.51x_1 + 0.11x_2 + 0.14x_3 + 0.36x_4 = 0.18$$

$$40x_1 + 20x_2 + 24x_3 + 30x_4 = g = \text{minimum and maximum}$$

(e) Maximization problem with inequalities.

$$2x_1 + 2x_2 + 2x_3 \leq 8$$

$$x_1 + 3x_2 + 2x_3 \leq 8$$

$$4x_1 + 2x_2 + x_3 \leq 8$$

$$x_1 + x_2 + x_3 = f = \text{maximum}$$

5 Civil Engineering 391. Problem 1. IBM 650. Computation of Stiffness and Fixed-End-Moment Coefficients. This is the first of three interconnected problems leading up to the analysis of statically indeterminate continuous beam by a relaxation procedure (moment distribution). The problem is primarily designed to give the student practice in:

a. Scaling by non-dimensionalizing the original problem.

b. Simple looping and address modification techniques.

c. Logical decisions based on the input quantities.

The quantities to be computed are the fixed end moments for statically indeterminate prismatic beams.

6 Mathematics 195. Problem 3. IBM 650. Period of a Simple Pendulum. The period, P, of a simple pendulum (see any elementary Physics text) with length L and amplitude θ_o is given by the infinite series expression

$$P = 2\pi\sqrt{\frac{L}{g}}\left\{1 + \left(\frac{1}{2}\right)^2 k^2 + \left(\frac{1\cdot 3}{2\cdot 4}\right)^2 k^4 + \left(\frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6}\right)^2 k^6 + \ldots\right\}$$

where

$$k = \sin \frac{\theta_o}{2}$$

and g is the gravitational acceleration.

When θ_o is very small $k = \sin \frac{\theta_o}{2} \approx 0$ and we have the approximation to P given by

$$P' = 2\pi \sqrt{\frac{L}{g}}$$

When θ_o is large enough to make k significantly different from zero, then more terms in the series must be included in order to get a good approximation to P. Consider the approximation which includes terms up to those involving k^8 and neglects terms involving higher powers of k; call this approximation P'', E, where

$$E = \frac{P'' - P'}{P''} .$$

Evaluate this for

$$\theta = 1^\circ \; (1^\circ) \; 20^\circ,$$

$$L = 1 \text{ ft.},$$

$$g = 32.258 \text{ ft/sec}^2 .$$

Use GAT variables X1, X2, X3, for θ, P'', E, respectively.

7 Mathematics 295. Problem 1. ILLIAC. Sexadecimal Multiplication Table. Write a program to print your name and course number and then to compute and print a sexadecimal multiplication table. The output format is to be in the form of a 15 x 15 matrix of two digit products with headings as indicated below.

	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L
1	01	02	.	.	.	.	.	.	.	.	.	.	.	.	OL
2	02	04	.	.	.	.	.	.	.	.	.	.	.	.	.
3	03	05	.	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

(continued)

```
K    .   .  .  .  .  .  .  .  .  .  .  .  .  .  .
S    .   .  .  .  .  .  .  .  .  .  .  .  .  .  .
N    .   .  .  .  .  .  .  .  .  .  .  .  .  .  .
J    .   .  .  .  .  .  .  .  .  .  .  .  .  .  .
F    .   .  .  .  .  .  .  .  .  .  .  .  .  .  .
L    OL  1F .  .  .  .  .  .  .  .  .  .  .  .  F1
```

8 Civil Engineering 391. Problem 2. IBM 650. Fixed-End Beam Moments. The class problem is to compute the fixed-end moments in a statically indeterminate beam. The mathematical method consists essentially of the repeated evaluation of an algebraic equation.

9 Electrical Engineering 322. Problem 1. IBM 650. Fourier Series Synthesis of Square Wave. Fourier series analysis on a square wave yields an infinite series of the form

$$v(t) = \frac{4V}{\pi} \sum_{n=1}^{\infty} a_n \cos n t$$

where

$$a_n = \begin{cases} +\frac{1}{n} & n = 1, 5, 9 \\ -\frac{1}{n} & n = 3, 7, 11 \\ 0 & n \text{ even} \end{cases}$$

For $V = \frac{\pi}{4}$, $v(t) = \sum_{n=1}^{\infty} a_n \cos n t$

Compute $v(t)$ for t from 0 to $\frac{\pi}{2}$ in steps of $\frac{\pi}{40}$ using a truncated series of N non-zero terms for N = 1, 2, ..., 10,

i.e., $v(t) \simeq \sum_{n=1}^{N} a_n \cos n t$

10 Mechanical Engineering 409. Problem 1. IBM 650. Collapse Rate of Bubbles. The solution of

$$R\ddot{R} + (2 - \frac{\epsilon}{2}) \dot{R}^2 = \frac{1}{\epsilon \rho_L} \left[P_v(t) - \frac{2\sigma}{R} - M_c \frac{\dot{R}}{R} \right]$$

$$\frac{\partial v}{\partial t} + \epsilon \dot{R} \frac{R^2}{r^2} \frac{\partial v}{\partial r} = \left(\frac{\partial^2 v}{\partial r_2} + \frac{2}{r} \frac{\partial v}{\partial r}\right)$$

where R is the collapse rate of the vapor bubble to be obtained.

11 Electrical Engineering 342. Problem 1. IBM 650. High Frequency Response of Transistor Amplifier. Compute gain in db and phase angle as a function of log f from

$f = 10$ kc to $f = 600$ kc ($\doteq$ 20 points)

The gain equation to be solved is

$$A_i = \frac{r_e - \dfrac{a_o}{(1+jf/_{fa})} \cdot \dfrac{r_c}{(1+jwr_cC_c)}}{r_e + R_L + \dfrac{r_c}{(1+jwr_cC_c)} \cdot \left[1 - \dfrac{a_o}{(1+jf/_{fa})}\right]} = \frac{I_o}{I_b}$$

r_e, r_c, R_L, C_c, b_o, and fa are to be read in as data.

PART VIII

GENERAL LABORATORY INFORMATION

Seminars

"Finite Difference Methods for Nonlinear Hyperbolic Systems", by Professor Murray Protter, University of California, Berkeley, California, October 9, 1961.

"A Description of ATHOS - An Automatic Operating System for the IBM 650", by Mrs. Jacqueline Flenner, Digital Computer Laboratory, University of Illinois, October 16, 1961.

"A Class of Optimally Efficient Encodings of Black-White Digitized Photographs", by Professor Bruce H. McCormick, Digital Computer Laboratory, University of Illinois, October 23, 1961.

"High-Speed, High Density Solid State Memory Devices", by Dr. J. Robert Schrieffer, Department of Physics, University of Illinois, October 30, 1961.

Reports

Report No. 112, "A Report on a Special Summer Computer Program for Undergraduates", by L. D. Fosdick, October 9, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	13	0	13.0
Research Associates	8	0	8.0
Graduate Research Assistants	11	19	21.1
Graduate Teaching Assistants	0	3	1.5
Administrative and Clerical	6	0	6.0
Other Nonacademic Personnel	39	14	45.95
TOTAL	77	36	95.55

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors, H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith and J. N. Snyder.

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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I	-	HIGH-SPEED COMPUTER PROGRAM
PART II	-	CIRCUIT RESEARCH PROGRAM
PART III	-	MATHEMATICAL METHODS
PART IV	-	ILLIAC USE AND OPERATION
PART V	-	IBM 650 USE AND OPERATION
PART VI	-	INSTRUCTIONAL USE OF COMPUTERS
PART VII	-	GENERAL LABORATORY INFORMATION

November 1961

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1) 415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1) 415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Construction Progress

Table I summarizes the progress during the month toward completion of the computer. Entries in Table I indicate the number of transistors which have completely passed through the phase of design or construction indicated by the column heading. Within one rectangle of Table I, the three figures from top to bottom indicate completions, respectively, at the beginning of the month, during the month, and at the end of the month. The transistor counts are intended to reflect the amount of work directly applicable toward completion of the computer, rather than total effort expended. For example, if the wiring of a chassis has to be modified, it is removed from the "completed" list, and indicated as having been wired again during the month in which the modification is made.

Completion of systems design indicates that the general strategy of design has been worked out in some detail. For a control, for example, a mnemonic order code would be fixed on completion of systems design, although the numerical equivalents for each order would be unknown. Logical design completion would be indicated by a logical diagram in which circuit restrictions on fanout and cascading are observed, but physical distances and consequent cable driver dircuits are not included.

Physical placement is completed when chassis boundaries are fixed, and cable driving circuits included in the logical diagram. In block layout, the function of each transistor on a chassis is indicated by circuit block symbols. Information sufficient for drafting, frame wiring, component layout, and power supply requirements is available on completion of block layout.

Component layout requires as many as 14 drawings for each chassis, showing successive phases of wiring of the chassis.

The static test involves application of D. C. power to the chassis before transistors are plugged into sockets. Voltage measurements at all nodes indicate faulty components, wiring errors, etc., not caught during visual inspections.

The column headed drafting indicates the completion of circuit schematics only. Thus, considerable drafting effort, such as preparation of logical drawings, figures for reports, etc., is not reflected in Table I.

A subsystems test is a dynamic test of several thousand transistors using a relatively simple fixed program usually generated by a small special purpose control to be discarded later. Systems tests can occur when sufficient equipment is assembled to run programs read from punched tape.

2. Subsystems Tests of Flow-Gating Buffer Storage Unit

The subsystems test of the 10 words of buffer storage in flow-gating was begun during the month. A special sequencing control was constructed to replace the transfer of 36 bits from register R to register M, during the Fibonacci test sequence*, by the following steps:

1) Transfer bits 5 to 40 of R to the corresponding digits of OUT register (word 0 of flow-gating).

2) Transfer 36 bits from OUT to word i+2 ($0 \leq i \leq 7$) of flow-gating.

3) Transfer 36 bits from word i+2 to IN register (word 1 of flow-gating).

4) Transfer 36 bits from IN to register M.

5) Replace i by i+1 (modulo 8).

Faults found during the month are summarized in Table II. Additional faults occurring during 546.6 hours of operation of the Arithmetic Unit are listed separately in Table II.

The subsystems test was considered complete when an error free run in excess of 50 hours was achieved. Since the arithmetic unit serves as a digit pattern generator for only 36 bits, two such error free runs are necessary for a complete test of the 52 bits of flow-gating. The first run, of 52.9 hours, was completed without error on November 25, 1961.

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* See March 1961 Technical Progress Report, Part I, Section 4

TABLE I

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Drafting	Subsystems Test	System Test
Repetitive M.A.U. 5379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	0
Core Storage Unit (4096 words) 3883	3,883	3,883	3,883	3,883	3,883	3,883	3,883	3,883	2,150		0
Delayed Control EAU, End Connections 11,200	11,200	11,200	11,200	5,210 2,274 7,484	3,484 1,520 5,004	2,664 1,560 4,224	1,982 861 2,843	284 1,368 1,652	1,025		
Flow Gating (Buffer Storage) 3987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,842	0 2,326 2,326	
Advanced Control 7000	6,040	1,950 3,550 5,500	0 1,950	0	0	0	0	0			
Drum Storage Unit 2500	2,500	800 0 800	0	0	0	0	0	0			
Interplay Control 3000	3,000	0 1,000 1,000	0	0	0	0	0	0			
Paper Tape Input-Output 641	641	641	641	641	641	508 133 641	319 322 641	0 189 189	0		
Test Controls	1,434	1,434	1,434	1,434	1,434	1,259 0 1,259	1,044 215 1,259	1,044 0 1,044	438	438 233 671	
TOTALS	38,064	29,274 4,550 33,824	26,524 1,950 28,474	20,534 2,274 22,808	18,808 1,520 20,328	17,680 1,693 19,373	16,594 1,398 17,992	14,577 1,557 16,134	12,835	5,817 2,559 8,376	

TABLE II SUMMARY OF FAULTS DURING SUBSYSTEM TESTS OF FLOW GATING

	Open Resistors	Missing Components	Wiring Error	Open Conn.	Faulty Diode	Faulty Transistor	Faulty Zener Diode	Bent Transistor Pin	Bad Socket Pin	Shorted Filter Capacitor	Shorted Conn.	Design Mistakes and Misc.	Totals
Flow Gating	10	4	10	32	5	6	3	6	13	4	3		96
Test Controls	1	1	5	12		1						2	22
Main Frame			1							24+			25
Arith Unit	4	1		6						3	1	1	16
Totals	15	6	16	50	5	7	3	6	13	31	4	3	159

+ See Section 3 of this progress report for additional details.

3. Circuits and Components

In view of the number of Main Frame Test runs which have been terminated by what appears to have been intermittent power failure, some effort has been spent on the design of an indicator system intended to aid in the detection of faulty module components. This system, which would consist of many inexpensive flip flops arranged to store the location of the "original" fault, has been tentatively designed and a model for attachment to a single module is being constructed.

To ease the problems of component layout within AC, it has been found desirable to admit the existence of a small class of restoring circuits having no output emitter followers. This subject is covered in File No. 417, "A Small Class of Restoring Circuits without OUTPUT Emitter Followers."

Tolerance analysis has been performed, in conjunction with C. Wallace, on the register flip flops and gates for interplay.

Experiments and analyses have been conducted with the aid of C. Carter and S. Ray on the problem of capacitor failure within the main frame. Preliminary voltage measurements indicated that an a.c. signal of tens of mv peak to peak, having a noticeable 500 kc component, existed across typical tantalum capacitors presently used to filter our 5 volt buss system. When informed of this, the capacitor manufacturers (iei) produced a first order calculation of the reactance of 200 μf at 500 kc which indicated very large a.c. currents in the capacitors. They had, of course, ignored resistive and inductive effects at 500 kc and were as a result orders of magnitude away from the currents actually measured by means of a current probe. The actual currents measured appear to be at least half the maximum allowable, although the manufacturer's specification is not very precise.

Measurements of turn on transient currents within the capacitors did not indicate anything very conclusive, however, a survey of the sudden rash of failures of capacitors on the 25v busses indicated a good correlation, with those modules having bypass resistors recently installed. Nevertheless, tests of 3 electrolytic and 3 tantalum capacitors, charged and discharged at about 10 cps by means of a mercury relay for a period of 1 week showed no effect.

J. Robertson had noted at a fairly early date that certain power busses acquired potentials, reverse to their normal polarity, during various stages of turn on. Measurements on a larger scale showed the +25 busses to

be particularly susceptible, during the time that low voltages alone are present. The reverse potential found of ≈ -2.5 volts is attributable to the nature of our circuits. A further test using reverse potentials applied by a mercury relay succeeded in destroying all three tantalum capacitors tested. A closer reading of manufacturer's fine print showed that iei tantalums in particular are intolerant of any reverse potential. Certain more expensive tantalums (G.E) are protected in this respect, and very cheap aluminum foil capacitors do not appear to be very strongly affected.

Germanium power diodes have been ordered to limit reversal of power busses to a few tenths of volts.

(K. C. Smith)

4. Advanced Control

During the month preliminary logical designs were completed for all outstanding gate and selector mechanisms, for the interrupt and special register area, the ACR and WF order registers, and the miscellaneous status memory elements. The DD/EE counter and associated equipment was extended to include interconnections with CCC and enabling logic for SAC. Various modifications and corrections were made to controls and mechanisms already designed, to correct errors and make them compatible with the various controls.

(R. R. Shively, D. B. Gillies)

The order code was assigned and a first version of the decoder was designed which is logically complete but must be reworked to include level-restoration and cable drivers, where required.

(K. Fuchi)

A first draft of the detailed logic of Sequential Advanced Control has been drawn up, based on the Flow Chart compiled last month. The logic comprises the control points with associated request and reply logic for the five steps of S.A.C., the two steps of ACR$\rightarrow$DCR Control and the two steps of Interrupt Control. There is some choice in the placing of request OR circuits and reply gathering AND's with respect to the control points and the other mechanisms of A.C. and the final decision will influence the type and disposition of cable-drivers that will be needed. The design procedure has therefore been the following:

(i) Control Points with all request OR's and decoder signals, and all OR-entry replies with bypasses where necessary.

(ii) Table of all reply signals and other conditions required to enable SAC control points and also those of C.C.C., O.W.C. and SCO.

(iii) Combine replies, where possible, to reduce loading on drivers and fan-in to enabling AND's. This is expedient because many replies have to enable several control points.

(iv) Decide on location of request OR's vis-a-vis mechanisms.

(v) Assess cable-driver requirements, conservatively.

(vi) Map logic.

(vii) Block layout.

Item (i) and part of (ii) have been completed, and it is expected that item (ii) to (vi) will be done by the end of the year.

(M. Faiman)

Address Arithmetic Unit

All bumps and cable drivers were assigned, and for 11 of the 12 chassis, preliminary layouts have been made assigning transistor numbers to every circuit. These have been checked for compatibility, and are ready to have all of the other details filled in.

(K. Mikami)

Logic diagrams combining large sections of the AAU are being prepared. One drawing entitled, "Registers, sCB, and CBOK Comparator of the Address Arithmetic Unit", containing 1030 transistors and comprising six chassis, Q11F, A11F, S11F, Q14F, A14F, S14F, has been completed. Sepia prints will then be used to fill in signal names, pin numbers, transistor numbers, etc., as block layouts for individual chassis are completed.

(T. A. Murrell)

5. Core Memory

The X and Y drivers were put into operation driving the lower half core stack. In addition to the usual number and kind of bad components and broken wires, the troubles of some interest were:

1) An intermittently open solid tantalum capacitor.

2) The large pulse component of the d.c. load was able to get into the regulator amplifiers and cause the output voltage to shift. This was cured by connecting 0.02 μfd ceramic capacitors from the output leads of the power supply directly to machine ground, i.e., with low inductance.

3) One signal transformer in the sense amplifiers had poor common-made rejection, i.e., its two primary windings were noticeably unbalanced.

The noise due to digit drivers was studied and it was clearly more insidious than that found in the previous model, due to the fact that some 13 times more drivers were now operating. The effects of this noise were reduced by shaping the digit lines as a more proper paired transmission line than previously.

The digit lines of the lower half core stack were rewired (by external jumpers) as indicated. This stack was completed on the 20th. After fixing some broken wires, it was found that three internal breaks in word lines had occurred. Finally, on the 29th, the memory would read and restore all 0's or all 1's at 2 μs cycle time.

At the end of the month, another type of noise, originating from the X and Y drivers was being studied.

(S. Ray)

6. Interplay

The writing of a detailed description of the system is nearly finished. The basic circuits have been slightly modified by K. C. Smith to accept the cheaper and faster 2N711 transistor. The circuit of the buffer flip flop has been laid out for wiring on standard chassis, mostly by L. J. Peek. Design of some of the area intermediate between Advanced Control and Interplay has begun.

(C. S. Wallace)

7. Paper Tape Editing

A further setback has occurred in the purchase by Tally Register Corporation of an IBM electric typewriter. This has involved a slight rearrangement of the type-face.

(C. S. Wallace)

8. Magnetic Drum Memory

The Magnetic Drum Memory circuit drawings are complete to the extent that fairly accurate transistor counts can be made, even though a number of important circuits have not been designed. The latest count of all the transistors to be contained in the Magnetic Drum Memory cabinet (the northern-most cabinet in the computer room) shows

2N1309	1670
2N1308	271
Indicator Transistors	184
Other Transistors	341
Total Transistors	2466

The frame for the Magnetic Drum Memory has been designed (Drawing 1309). It is 88 1/8" tall, 30" deep and 93 1/4" long, not counting the doors. It is similar to the 12 bay slice (6 bays on a side) of the Main Arithmetic Unit up to the 88 1/8" level. It contains 4 full bays, each containing one 12 x 24 and two 12 x 18 chassis, plus 8 short bays over the two drum boxes. The short bays will hold the write and read amplifiers and head selection circuits in special chassis which use the standard 12 x 24 chassis aluminum frame, but have radically different internal construction.

(H. C. Brearley)

Reading and writing experiments were performed on the magnetic disc using the cyclic pattern generator, read-write head selection matrix and peak detector. The test was not final. More work is needed to make the derivative circuit of the peak detector work reliably. A new peak detection circuit has been built and is to be tested.

A checking circuit for the bit clock track was studied and designed. It checks that (1) at least one bit pulse occurs in every sector, (2) the positive and negative pulses alternate, and (3) the first pulse in each sector is a positive one. A similar circuit was developed to check the behavior of the peak detector.

Two short reports were written on the peak detection circuit and the bit clock pulse checking circuit. The large report on the logic circuits for the drum memory is being put in final form.

(M. Falleni)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Introduction

Tunnel-diode work was divided into two parts: T. Moto-Oka examined the more theoretical aspects of switching for both single and twin diode circuits and H. Guckel, aided by S. Ribeiro, performed some very exact DC measurements on available units. These were undertaken because a suspicion arose that actual units were far from ideal: The experiment showed a most unusual "corrugated valley" effect. This work is more fully reported on in Parts 2 and 3.

S. Ribeiro continued his work on the theory of supersaturation. It was found that as long as $w < L_p$ for the base, no gain could be produced in saturating units even when the first approximation was replaced by a more exact solution. It is now hoped that one can plausibly assume that $w > L_p$ by postulating a complete disappearance of the collector junction: w would then extend from the emitter to the collector contact. Details follow in Part 4.

T. Burnside made the first steps towards an analytic probability theory of circuits. Some of his reasonings are shown in Part 5.

The work of J. Hill on failsafe circuits made some progress, but a report will be deferred until an actual set of circuits can be shown.

2. Experimental Tunnel-Diode Work

Examination of tunnel-diodes as devices was continued. Particular interest was given to a measurement of the negative impedance region. Measurements were effected by:

a) Bridge at 500 MC
b) Milliammeter - Millivoltmeter
c) Curve Tracer
d) Difference Amplifier
e) Galvanometer

Even though the theory is understood well enough, the physical realization of this type of measurement is difficult due to the perturbation introduced by the measurement apparatus itself. This means that due to the very steep slopes of the device in the V-I phase any ripple or drift introduced by the measuring instrument, or the source etc. will result in an error, visible as an oscillation in the read-out device or an erroneous read-out. In order to eliminate some difficulties the circuit of Figure 1 was used.

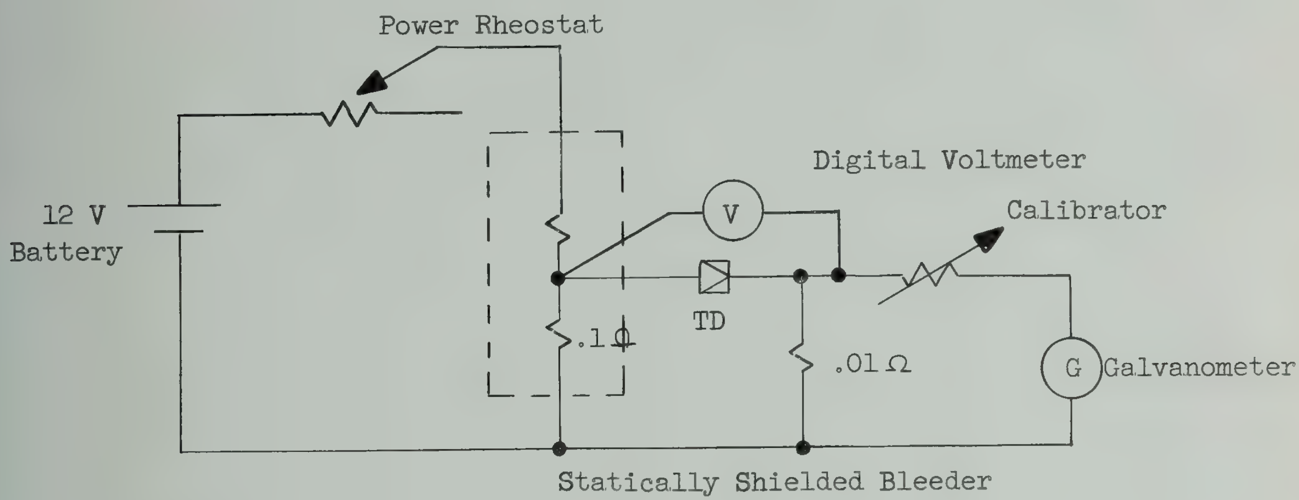

Figure 1

DC Tunnel-Diode Test Setup

The results obtained so far indicate the characteristic shown in Figure 2:

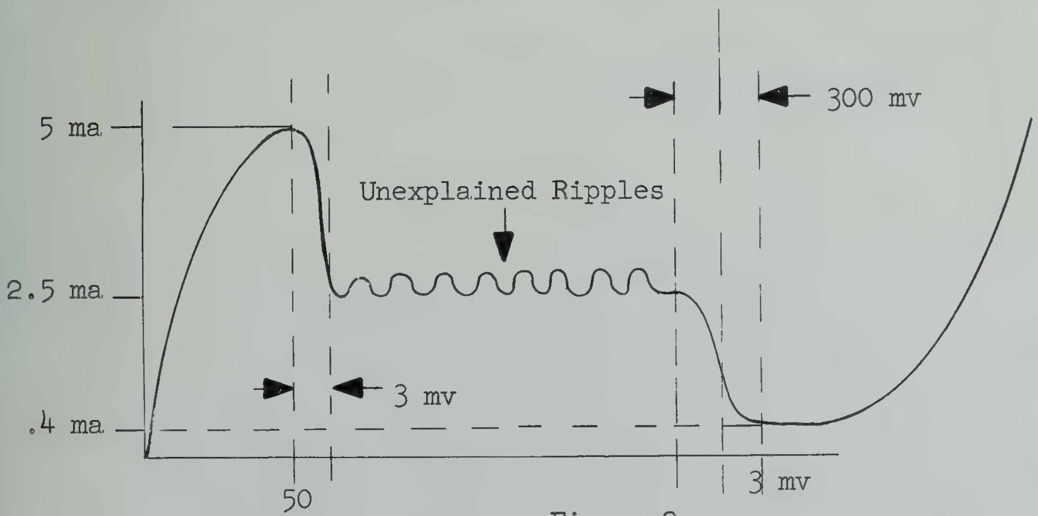

Figure 2

DC Tunnel-Diode Characteristic

This information is not be be taken as final information but only as a trend. The investigation will be concluded shortly.

3. Theoretical Tunnel-Diode Work

In order to design high-speed tunnel-diode switching circuits, it is necessary to explain some concepts of switching time and triggering characteristics of these circuits. For this purpose, the analytical and graphical analysis of these characteristics was investigated on a single tunnel-diode circuit.

In order to simplify the analysis, the equivalent circuit of a tunnel-diode shown in Figure 3 was used. In this circuit, the shunt capacitance has a constant value and the series impedance is neglected.

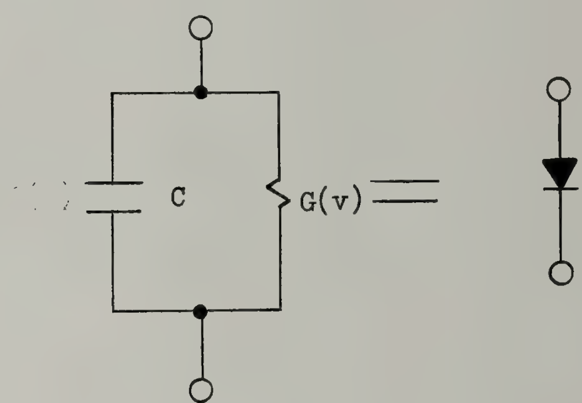

Figure 3

Simplified Equivalent Circuit of the Tunnel-Diode

As a typical switching circuit, a circuit with a load resistance R_L and constant current source I, shown in Figure 4(a) was investigated.

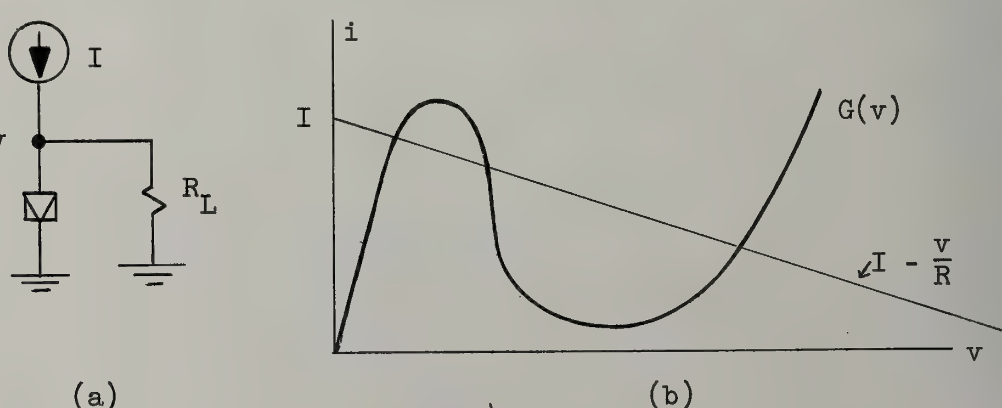

Figure 4

Typical Switching Circuit

The circuit equation of this circuit is

$$C \frac{dv}{dt} + f(v) + \frac{v}{R_L} = I \qquad (1)$$

where $f(v) = G(v) \cdot v.$

The physical meaning of this equation is that the difference of i-axis values of two curves shown in Figure 4(b) is proportional to the switching speed at that point. In order to obtain the real switching time, it is necessary to integrate the equations numerically by using a computer. To obtain a first idea, however, it was decided to calculate the solution analytically by approximating the tunnel-diode characteristics by a curve of degree 3:

$$F(v) = I - f(v) - \frac{v}{R_L}$$

it was assumed that

$$F(v) = -\, a\,(v-\alpha)\,(v-\beta)\,(v-\gamma) \qquad (2)$$

and it was postulated that there are three intersections of the curves, given as $v = \alpha, \beta, \gamma$ in Figure 5(a). The switching time is now given by

$$T_S = C\left[\frac{1}{F'(\alpha)} \log|v-\alpha| + \frac{1}{F'(\beta)} \log|v-\beta| + \frac{1}{F'(\gamma)} \log|v-\gamma|\right]_{v=v_0}^{v_1} \qquad (3)$$

where v_0 is the initial voltage and v_1 the final one. Switching time and switching waveform are shown in Figure 6.

If we have only one intersection of the two curves, as shown in Figure 5(b) F(v) can be written

$$F(v) = I - f(v) - \frac{v}{R_L} = -\, a\,(V-\beta)\,(V^2+\beta V+\beta^2-3\alpha^2) \qquad (4)$$

where $v = V + \frac{V_p+V_v}{2}$, and the intersection is given by $V = \beta$. The peak voltage is $V_p = -\alpha$, the valley voltage $V_v = \alpha$ as shown in Figure 5(b). Here,

$$T_S = \frac{C}{3a(\beta^2-\alpha^2)} \left[\frac{1}{2} \log \left| V^2+\beta V+\beta^2-2\alpha^2 \right| + \frac{\sqrt{3\beta}}{\sqrt{\beta^2-\alpha^2}} \tan^{-1} \frac{2V+\beta}{\sqrt{3(\beta^2-\alpha^2)}} - \log |V-\beta| \right]_{V_0}^{V_1} \quad (5)$$

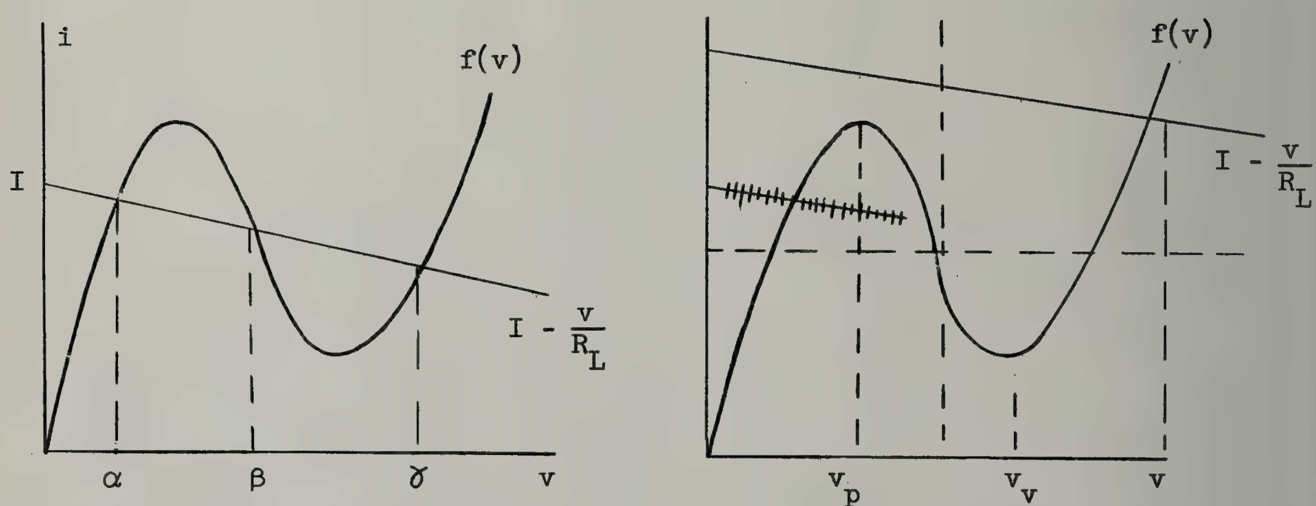

Figure 5

Notation for the Approximate Expressions for F(v)

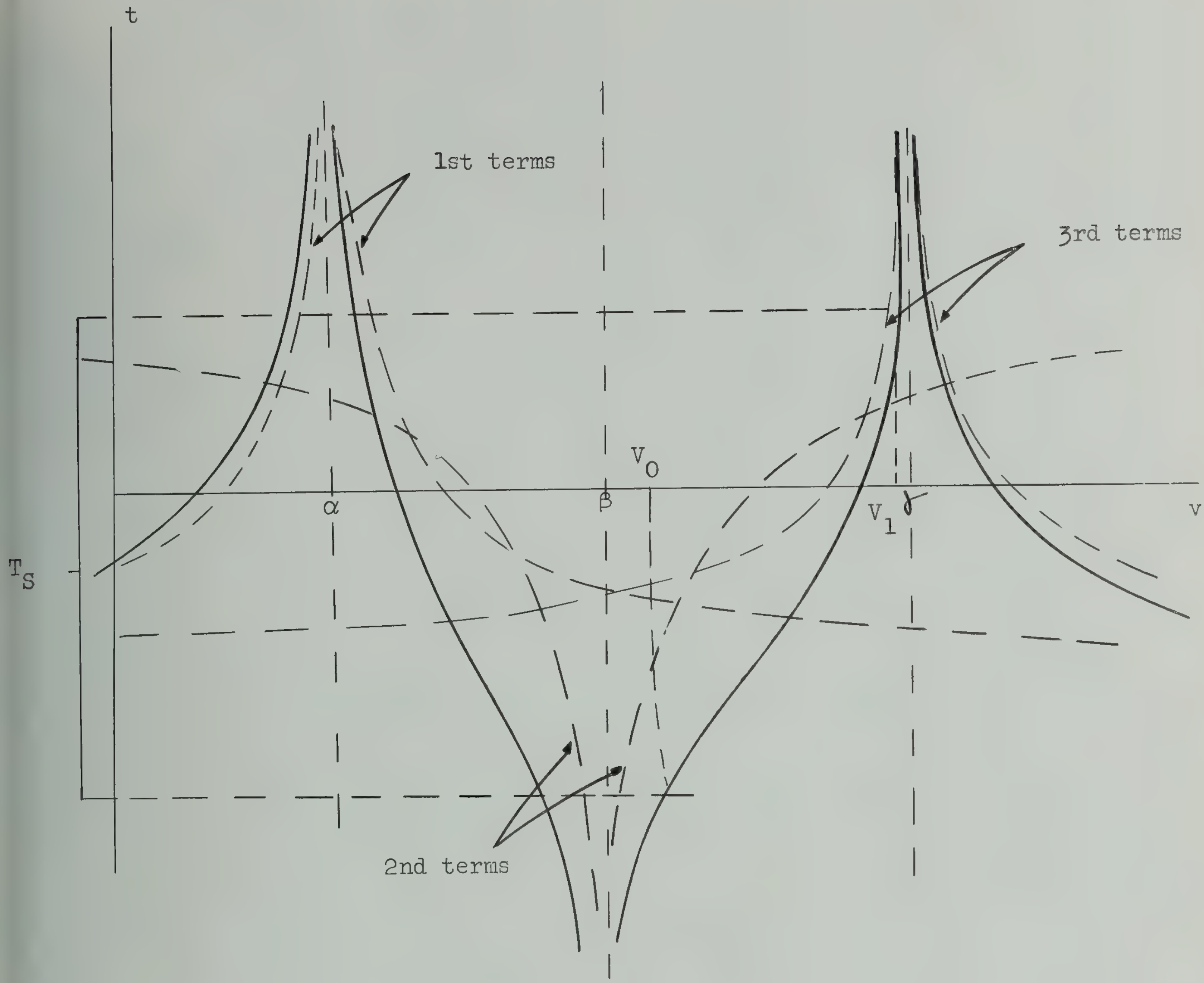

Figure 6 - Switching Waveform for a 3 Point Intersection

The switching time and switching waveform of this case are shown in Figure 7.

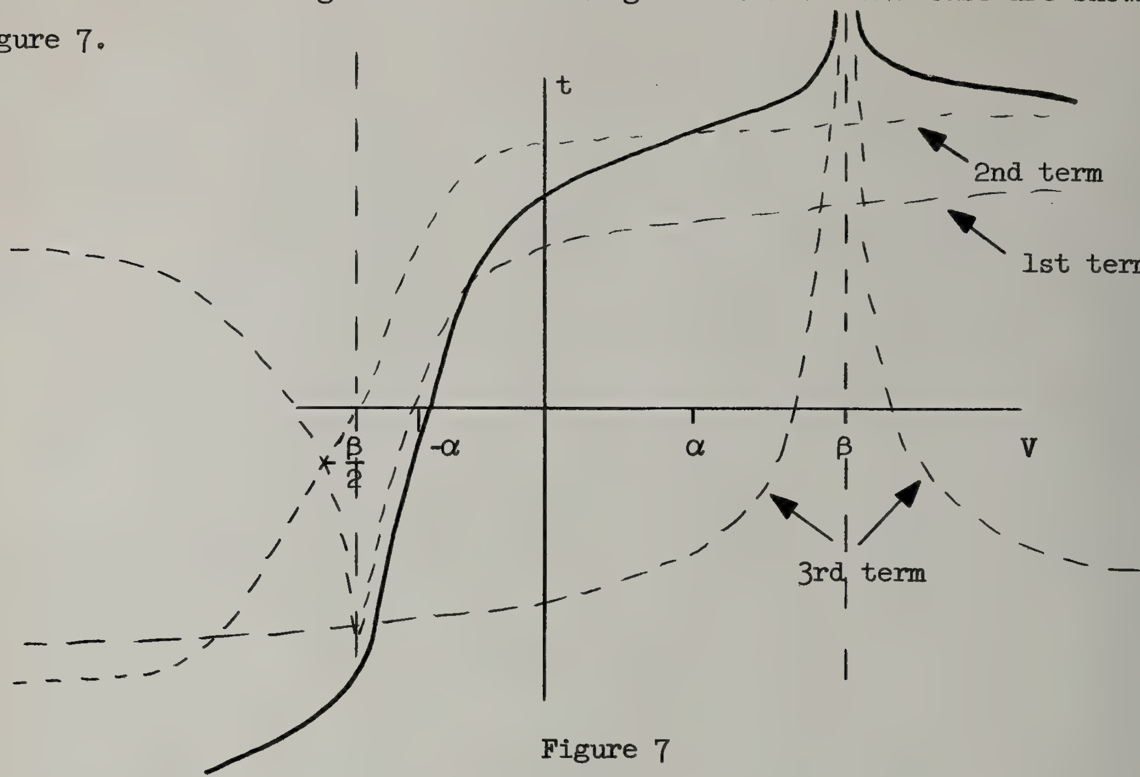

Figure 7

Switching Waveform for a 1 Point Intersection

The trigger characteristics of cascaded tunnel-diode circuits were investigated too. The circuit equations of a resistance coupling circuit shown in Figure 8, are:

$$C_1 \frac{dv_1}{dt} + f_1(v_1) + \frac{1}{R}(v_1 - v_2) = I_1$$

$$C_2 \frac{dv_2}{dt} + f_2(v_2) + \frac{1}{R}(v_2 - v_1) = I_2 \ . \tag{6}$$

The topological properties of these ordinary differential equations are shown in Figures 9 and 10. These figures were obtained graphically by using real tunnel-diode DC characteristics. The tunnel-diode used has a peak current of 21 ma. Since the definition of power amplification is

Power Amplification Factor

$$= \frac{\text{Energy stored in capacitance when it is switched}}{\text{Necessary energy for switching}} \ ,$$

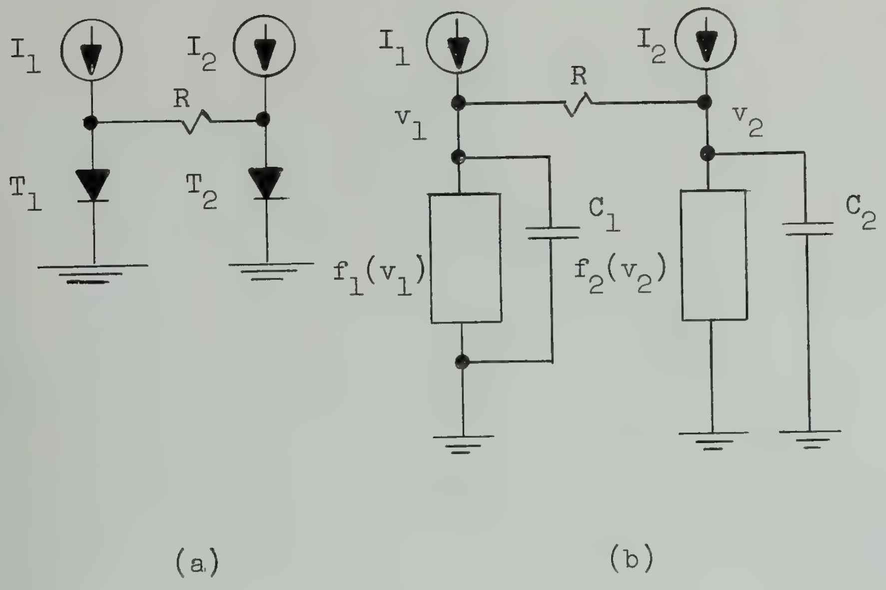

Figure 8

R-Coupling Twin Tunnel-Diode Circuit

the circuit shown in Figure 9 has no power amplification while the circuit in Figure 10 has a p.a.f. larger than 1.

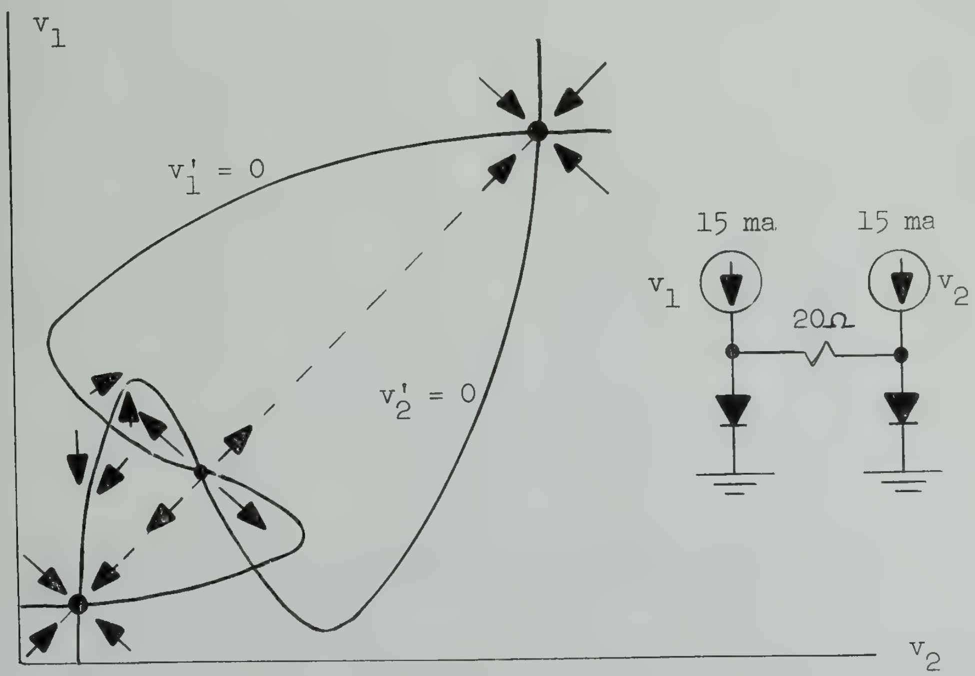

Figure 9

Graphical Analysis of Trigger Characteristics

(Symmetrical Case)

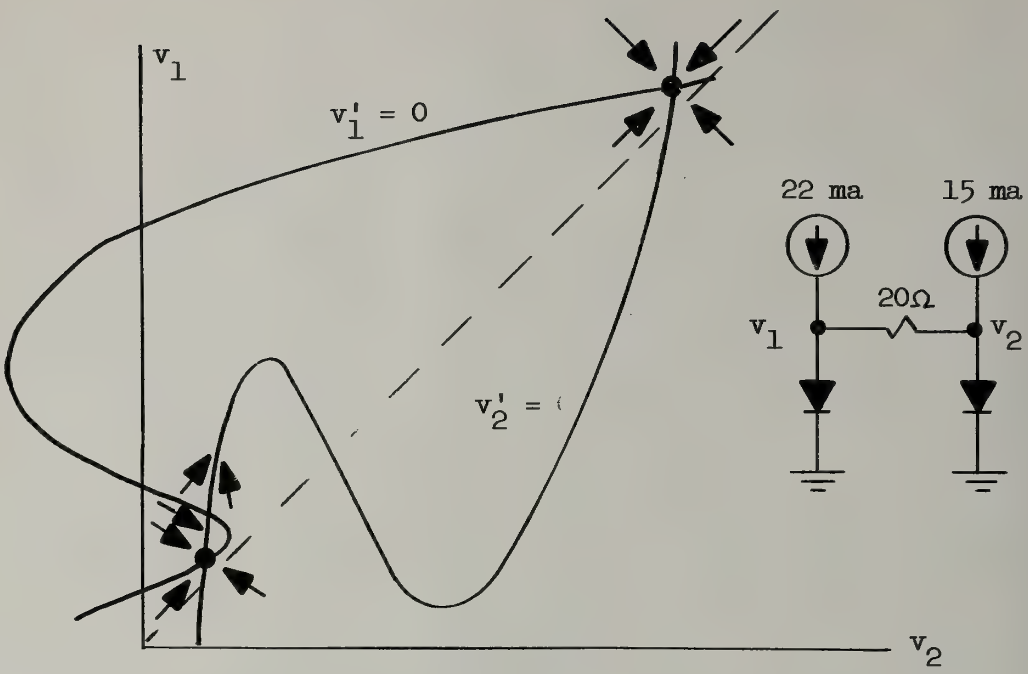

Figure 10

Graphical Analysis of Triggering Characteristics

(Asymmetrical Case)

4. <u>Supersaturation</u>

The theoretical study of the supersaturation effect has been continued.

Since the approximate analysis based on the change in quasi-Fermi level due to changes in the hole density in the base did not succeed in explaining the effect, another attempt was made by solving the diffusion equation, in a more exact manner, for the small signal case. It was found that this solution again did not explain the effect, for the assumption $\frac{W}{L_p}$ small would reduce it to the approximate equation already obtained, unless extremely high frequencies are involved. Since the effect is a low frequency one, this theory was not investigated further.

A new hypothesis is being tried, which consists in assuming that recombination takes place in the whole body of the transistor, and that consequently, the phenomemon is due mostly to electron injection from the base into the emitter and collector regions (electrons being then minority carriers in most of the volume).

5. Analytic Circuit Probability Theory

It was desired to find the output voltage distribution of a circuit with a given input voltage distribution and known distributions of the circuit parameters. As a first step consider $z = f(x,y)$ where the distributions $p(x)$ and $q(y)$ of two independent variables x and y are known (see Figure 11). The probability density $r(z)$ can then be found by the following argument:

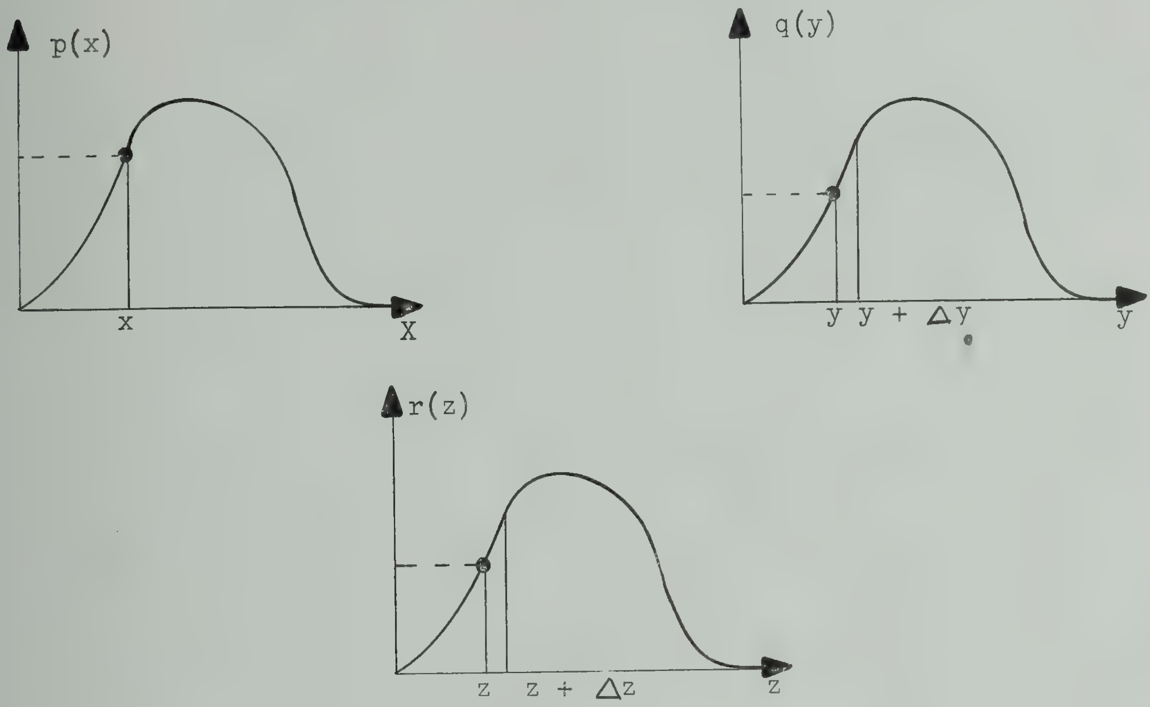

Figure 11
Composite Distribution Curves

Hold x constant, i.e., between x and x + dx and increase y by Δy where $\Delta y \gg dx$ to give $z + \Delta z = f(x, y + \Delta y)$. Then:

$$\Delta z = \Delta y \frac{\partial f}{\partial y} = \Delta y \left(\frac{\partial z}{\partial y}\right)_x \qquad (1)$$

The probability that y is between y and $y + \Delta y$ is $q(y)\ \Delta y$ when Δy is small. Likewise the probability that z is between z and $z + \Delta z$ is $r(z)\ \Delta z$.

If x is allowed to vary over all of its range

$$r(z)\,\Delta z = \int_{-\infty}^{+\infty} p(x)\ dx\ q(y)\,\Delta y$$

$$= \int_{-\infty}^{+\infty} p(x)\ q(y)\,\Delta z \left|\left(\frac{\partial y}{\partial z}\right)_x\right| dx$$

$$r(z) = \int_{-\infty}^{+\infty} p(x)\ p(y) \left|\left(\frac{\partial y}{\partial z}\right)_x\right| dx \qquad (2)$$

In the equation above, y should be expressed as a function of x and z. This assumes that the inverse function is monotonic.

This result can be applied to some common functions. Two of these are

$$z = xy \quad \text{and}$$

$$z = y-x.$$

In the first case $y = \frac{z}{x}$, $\frac{\partial y}{\partial z} = \frac{1}{x}$

$$r(z) = \int_{-\infty}^{+\infty} p(x)\ q\left(\frac{z}{x}\right) \frac{dx}{x} \qquad (3)$$

In the second case $y = x + z$, $\frac{\partial y}{\partial z} = 1$

$$r(z) = \int_{-\infty}^{+\infty} p(x)\ q(x+z)\ dx \qquad (4)$$

which is the result that had been noted last month.

Another case of interest is $z = f(y)$. Here $x = 1$ always, and it is seen that

$$\int_{-\infty}^{+\infty} p(x)\ dx = 1$$

is not a function of either y or z, meaning that

$$r(z) = q(y) \left|\frac{\partial y}{\partial z}\right| = q(y) \left|\frac{dy}{dz}\right|$$

$$|r(z) \ dz| = |q(y) \ dy| \tag{5}$$

An application of these results can be made to the simple diode circuit shown in Figure 12.

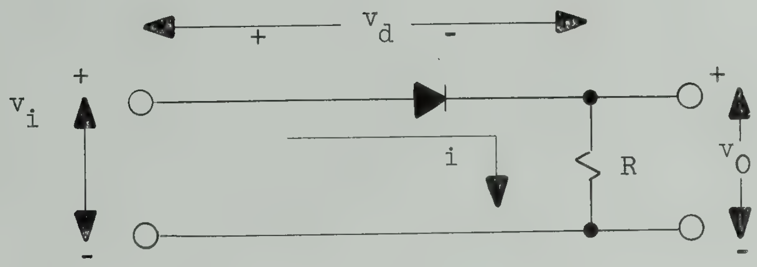

Figure 12

Diode Circuit for Probability Analysis

The characteristic equations are

$$i = i_o \left(e^{\frac{v_d}{V_T}} - 1 \right)$$

$$v_o = i R$$

$$v_i = v_d + v_o.$$

Assume that the temperature and therefore V_T is constant. If $p(v_i)$ and $q(v_d)$ are known, we would like to know $r(v_0)$. $q(v_d)$ varies with both v_d and i. However $s(i_0)$ is a function of only i_0: $s(i_0)$ will be found in terms of $q(v_d)$ for a particular current, $i = i_c$.

$$s(i_0) = q(v_d) \left| \frac{dv_d}{di_0} \right| \quad (i = i_c)$$

$$v_d = V_T \ln \left(\frac{i_0 + i_c}{i_0} \right)$$

$$s(i_0) = p(v_d) \Bigg|_{i_c} \frac{V_T \, i_c}{i_0 \, (i_c + i_0)}$$

Combining the characteristic equations

$$v_0 = i_0 R \left(e^{\frac{v_i - v_0}{V_T}} - 1 \right).$$

If $v_d = v_i - v_0$ is small enough

$$v_0 \doteq i_0 R \left(1 + \frac{v_i - v_0}{V_T} - 1 \right)$$

$$v_0 = \frac{i_0 R v_i}{V_T + i_0 R} \qquad v_i = \left(\frac{i_0 R + V_T}{i_0 R} \right) v_0$$

$$\frac{\partial v_i}{\partial v_0} = \frac{V_T + i_0 R}{i_0 R}$$

$$r(v_0) = \int_{-\infty}^{\infty} p(v_i) \, s(i_0) \left| \frac{v_i}{v_0} \right| d\, i_0$$

$$r(v_0) = \int_{-\infty}^{+\infty} p(v_i) \, q(v_d) \Bigg|_{i=i_c} \frac{V_T \, i_c \, (V_T + i_0 R)}{i_0^2 \, R \, (i_c + i_0)} \, d\, i_0$$

PART III

MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Monte Carlo Methods in Quantum Statistics

Some calculations were made with the new program, NUMBER 6.21 which is like NUMBER 6 (See September Technical Progress Report) except that it permits a smaller integration step size for calculating

$$\int_0^1 V \, d\tau$$

where V is the potential energy function for the two-particle system. In these computations some earlier runs with program NUMBER 6 were repeated with a step size smaller by a factor of 1/3. The results were not changed by this reduction in step size. Because of the large amount of computation required (approximately 4 3/4 hours for sample size of 100) for this work only a few tests were made. However, on the basis of this small number of results it seems reasonable to suppose that the integration step size is not the most important factor contributing to the discrepancies between the exact results and the Monte Carlo results.

We next propose to test the effect of changing slightly the random number distribution.

(L. D. Fosdick)

PART IV

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of November, one new routine was added to the Illiac Library.

KA 2 - 331 Automatic Polynomial Approximation (SADOI). This program may be used to find, approximately, that polynomial of given degree which best fits the given function in the interval $[-1, 1]$. The approximating polynomial of given degree which best fits a given function in a given interval in the Chebyshev sense is that polynomial of the given degree which has the smallest maximum deviation from the given function in the given interval.

The two modes of operation are:

Mode I: This mode is used if the given function is itself a polynomial of degree ≤ 49 whose coefficients are either given on the data tape, are left in the machine from a previous problem, or are computed during input by an interlude supplied on the data tape.

Mode II: This mode is used if the given function is not itself a polynomial of degree ≤ 49. Two auxiliary subroutines, one to calculate the function and the other to calculate its first derivative, must either be supplied on the data tape or left in the machine from previous problem.

In Mode I, the preliminary approximating polynomial is obtained by polynomial economization; that is, by subtracting multiples of appropriate Chebyshev polynomials from the given polynomial. In Mode II, the preliminary approximating polynomial is obtained by interpolation; that is, by evaluating the given function at selected points in the interval $[-1, 1]$ and then passing a polynomial through these points.

In either mode, the routine then uses a modified Lagrangian interpolation process to find an approximation to the given function in $[-1, 1]$ which is of the same degree at the preliminary approximating polynomial but which is better in the sense that its extrema are more nearly equal. This process is repeated until a polynomial is found whose extrema differ from each other by less than 1%, whereupon this is taken as the final approximating polynomial.

(Clinton Foulk)

Illiac Usage

During the month of November, specifications were presented for 18 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2093T. Numbers followed by T are for theses.

2093T Agricultural Economics. Cost-Size Relationships on Western Illinois Farms. Farm resource models are constructed for five different farm size groups in a study of the cost-size relationships that exist on farms in western Illinois. Linear programming can then be used to determine optimum levels of output from each farm size and thereby compute unit costs associated with this set of resources.

The Illiac will aid in the solution of this problem by solving the linear programming problems which are the basis of the study. These solutions will involve the inversion of matrices of size 11 x 11. The contribution of the Illiac in this regard will be considerable in terms of releasing the researcher for work on interpretation and implications.

2094 Psychology. Psychology of Forest Use. Case data, personality tests and forest plot data was gathered on a large group of rural farm operators in an area of central Illinois and in an equivalent area of southern Illinois. The problem is to determine why some farm operators make economic and/or recreational use of their forests and woods lands while others do not.

The case data and forest plot data is to be factored to determine what the dimensions underlying this problem might be. The personality tests will relate these people's general behavior to that exhibited by the standard population.

2095T Civil Engineering. Plates on Elastic Medium. The problem will be the analysis of plates on elastic layers.

Finite difference methods will be used to solve the partial differential equations of elliptic type, especially the plate biharmonic equation.

The system of simultaneous linear equations obtained will be solved by either library routines L-6 and L-7 or by an iterative procedure, depending on the number of equations.

The iterative procedure will be essentially similar to that of the systematic iteration procedure of Gauss-Seidel.

2096T Psychology. An Analysis of Intrafamilial Relations Through a Process of Idealized Individuals. This research is concerned with obtaining parental perceptions of intrafamilial relations and examining the factor structure of idealized individuals by a statistical process recently introduced.

The original data is in the form of a score on a seven point rating scale. This data will be converted from this positive number (the rating being from one to seven) to a number on a scale from -3 to +3 by a program which has been written by the investigator. These will in turn be submitted for a sum of cross-products between individuals and across scales utilizing a matrix multiplication by a transpose program which has been written. The eigenvectors and eigenvalues will then be extracted from this "people" space and the eigenvalues examined to determine the per cent of sum of squares accounted for by cumulative roots. The projections of the eigenvectors will then be plotted and interpoint distances determined on the resultant vectors formed by the projections of the eigenvectors. By the use of M-28, the entries corresponding to these points in the matrix of scales and concepts will be determined by rotating the A matrix to orient an axis along the direction describing an ideal individual and apply the inverse of this transformation to Y. These transformed entries will now be treated as the scale of the interpoint distances for the idealized person corresponding to the direction and analyzed multidimensionally by the use of KSL 1.80.

2097 Physics. T-Matrix Off Energy Shell. An analytic expression has been obtained for the t-matrix off the energy shell with a square well potential. The values of this matrix are to be calculated for various values of the potential depth, center of mass energy, initial and final momentum.

The expression to be evaluated is

$$t = \beta^2 \frac{q^2 - q_i^2}{\alpha^2 - q_i^2} F(q_i, q_f) + \frac{\beta^4 F(q_f, \alpha)}{1-\beta^2 j_0^2(\alpha)} \frac{\left[\cos q_i \cos \alpha + q^2 j_0(q_i) j_0(\alpha)\right]}{\alpha^2 - q_i^2}$$

$$+ i \frac{\beta^4 q}{1-\beta^2 j_0^2(\alpha)} F(\alpha, q_i) F(\alpha, q_f)$$

$$F(x, y) = \frac{j_0(x-y) - j_0(x+y)}{2xy}$$

$$\alpha^2 = \beta^2 + q^2$$

$$\beta^2 = \frac{2\mu V_0 R^2}{\pi^2} \text{ - depth parameter}$$

q = center of mass momentum

q_i = initial momentum

q_f = final momentum

About 1,000 sets of parameters will be calculated.

2098 Psychology. Student Evaluation of Teaching Ability. This is an exploratory study to examine the feasibility of determining the factors in student evaluation of teaching ability.

Intercorrelations among items, principal component factors, oblimax rotations of these factors and centroid second-order factors will be obtained.

2099 Agricultural Economics. Farm Production and Financial Programming. Financial and production data from farm records and a survey of banks and production credit association will serve as a basis for the coefficient matrix and the requirements vector of a linear programming problem. The optimum farm plan will be derived from alternatives including borrowing in various periods of the year. The requirements to be met by the plan include meeting debt obligations. Thus, the usual production oriented linear programming model is modified to embrace the financial aspects of planning. The standard routine M29-295 will be used.

2100 Psychology. Dimensional Analysis of U.I. 19, 20, 23 Markers. This is the first stage of a project designed to improve measures of three personality dimensions, known as U. I. 19, U. I. 20, and U. I. 23. The first stage is a factor analysis of variables known to be "markers" for these dimensions. This will be followed by an "extension" analysis which will give the correlation of a series of new measures with the factors extracted by the factor analysis.

2101 Mechanical Engineering. Heat Conduction in Solid. The object of this program is to compare the exact differential method and the relaxation method for the solution of a simple heat conduction problem in a solid. The residues for each method will be inspected.

2102 Physics. Electronic States on Dislocations. In constructing variational wave functions for electrons trapped in the strain field of a dislocation in a semiconductor a sixth order secular equation must be solved. The Illiac is to be used to obtain the eigenvalues and eigenvectors of this system of equations for several types of dislocations.

2103 Mining and Metallurgical Engineering. Low Temperature Specific Heat Measurements. In the expression

$$C_i = A + \gamma T_i + \beta T_i^3$$

low temperature specific heat measurements give the value of C as a function of temperature, T. The parameters A, γ and β are to be computed by the least squares method from the above equation and the C_i vs. T_i data. In the equation A is a specific heat term arising from magnetic clusters, γT is the electronic specific heat term, and βT^3 is the lattice specific heat term.

2104 Psychology. Group Factors in Creativity. The purpose of this research is to match two students according to their response to a series of personality and creativity tests.

About 130 students have taken a series of personality and creativity tests. Eighteen measures of personality and five measures of creativity will become available. These will be subjected to standard statistical and factor analytic procedures.

2105 Coordinated Science Laboratory The Structure of Strong Shock Waves. The Boltzmann equations for a steady state shock wave may be written as

$$v_x \frac{\partial f}{\partial x} = a - b\,f$$

where

$f = f(\vec{v}, x)$ is the molecular velocity distribution function and

$(a - b\,f)$ is the collision integral.

The functions a and b are evaluated, by a Monte Carlo method, for $f = f^{(0)}$, the zero-th approximation to f. The Boltzmann equation is then integrated for each velocity bin to give $f^{(1)}$, the next approximation to f. Iteration of this procedure is carried as far as is appropriate in view of the fluctuations in the a, b caused by the Monte Carlo evaluation. These fluctuations are reduced within each iteration by smoothing.

Calculations will be made for a range of shock strengths. Various characteristics of the numerical method will also be studied.

2106T Civil Engineering. Analysis and Design of Three-Span Continuous Highway Bridges. This problem is concerned with the development of a simplified method of analysis and design for a three-span continuous highway bridge subjected to moving loads. In the course of the investigation it is planned to accumulate and study both the analytical and the available experimental data on the subject. In the first stage of this investigation it is desired to obtain an extensive number of additional solutions covering more fully the significant parameters by making use of available codes for the problem.

2107T Civil Engineering. Multivariate Analysis of Vehicular Speeds. This problem is concerned with identifying and evaluating those travel conditions that significantly influence vehicular speeds. A parsimonious description of this complex phenomenon is being sought through a factor analysis of 50 travel variables with a sample size of 473. In addition, factor scores are to be determined to permit the estimation of vehicular speeds in terms of the factors generated.

After the results of the factor analysis have been evaluated, a multiple linear regression analysis will be performed to establish the

functional relationship between average speed and a selected number of independent variables.

Computer routines for the factor analysis are available only for the Illiac.

2108 Agricultural Engineering. Linear Regression Analysis. The object of this research is to obtain data on the energy dissipation at the entrance of a four inch copper tube for various entrance conditions. The data consists of static pressure measurements taken from piezometers equally spaced along a test pipe.

Illiac is to be used to compute the linear regression line for each of many sets of data (approximately 125). The regression equation thus determined is to be used to compute the amount of energy dissipation caused by the entrance condition.

2109 State Water Survey. Low Flow and Reservoir Capacity Analysis. The study involves the analysis of approximately 50 years of stream flow records at 170 stations in Illinois to determine an estimate of reservoir capacity necessary to meet certain water requirements during a certain recurrence interval drought.

Stream flow measurements will be used in calculation of moving averages for periods of one month to 60 months, a complex sorting on each generated series of running totals to determine an estimate of the low flow frequency distributions, and computations to determine reservoir capacity based on the various low flow series.

In addition to printing the low flow series and the reservoir capacity analysis, the program will prepare and output for the data plotter for both reservoir capacity and low flow. The low flow series and the reservoir capacity data will be plotted on separate graphs. However, both sets will be on logarithmic versus Gumbel scales.

2110 Digital Computer Laboratory. Q5 - DCL Test Control. The purpose of this program is to determine whether the logical circuit which controls the flow gating memory of Illiac II in the test mode is speed independent or not, and if not, where it fails and why.

Table I shows the distribution of Illiac machine time for the month of November.

TABLE I

	Hrs:Min	
Scheduled Maintenance	66:13	
Unscheduled Maintenance	15:25	
Drum Engineering	4:28	
Leapfrog	4:02	
Library Development	2:16	
Classes	27:22	
Instruction	:01	
Wasted	:01	
Demonstrations	:27	
		120:15

Use by Departments

Aeronautical Engineering	2:45
Agricultural Economics (APPRAISAL 47 15 05 334)	:03
Agricultural Economics	22:10
Animal Science	2:39
Astronomy (NSF-G-14834)	8:30
Bureau of Economic and Business Research	1:04
Bureau of Educational Research (PH-M1839)	3:17
Bureau of Educational Research	:21
Chemistry (NSFG-5907)	:04
Chemistry	71:56
Civil Engineering (HIGHWAY BRIDGE IMPACT)	:04
Civil Engineering (DA-104)	3:02
Civil Engineering	34:29
College of Medicine	1:54
Coordinated Science Laboratory (DA-36-039-SC56695)	83:37
Digital Computer Laboratory (NONR 1834(27))	67:26
Digital Computer Laboratory (US TR AEC-1018)	3:09
Digital Computer Laboratory	1:25
Economics (NSFG 7056)	5:02
Education	5:35
Electrical Engineering (NONR 1834(22))	:23
Electrical Engineering (AF 7043)	14:31
Electrical Engineering (NOBSR 64723)	1:18
Electrical Engineering (AF 33(616) 6079)	:47
Electrical Engineering (NSFG 19005)	5:40
Electrical Engineering (NSFG 14894)	:31
Electrical Engineering	5:06
Finance (IHR-71)	1:14
Food Technology (50-343)	11:02
Horticulture (00 15 65 330 38)	:24

Illinois State Normal University	:09
Institute of Communications Research (44-28-20-378)	4:32
Institute of Communications Research (USPHM-3941)	4:34
Institute of Communications Research	:47
Institute of Labor and Industrial Relations	:53
Mechanical Engineering	21:57
Mining and Metallurgical Engineering (TRUS AF 6770)	:14
Mining and Metallurgical Engineering	:43
Music	1:18
Natural History Survey	:33
Office of Instructional Television (OE 7-11-107.00)	1:48
Physics (NONR 1834(05)A)	2:03
Physics (NSF 14 308)	1:32
Physics	7:20
Psychology (1715)	1:02
Psychology (MD 2060)	:18
Psychology (AF 41-657-279)	:16
Psychology (AF 49(638)371)	10:06
Psychology (USPH 45-32-66-373)	2:54
Psychology (ONR 46-32-66-362)	:21
Psychology	64:48
Sociology	1:19
State Water Survey	25:01
State Water Survey (DA-36-039-SC75055)	1:55
Theoretical and Applied Mechanics (DA-11-070-508 ORD)	10:21
Theoretical and Applied Mechanics (DA-01-021 ORD 11878)	1:25
Veterinary Physiology	:04

527:45

648:00

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns,

and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Memory	1
Reader	4
Punch	5
Input-Output	1
Drum	13
Printer Control	2
Power Supplies	1
Unknown	1
Total	28

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
11/1/61	20:58	:00	3:02	0		:00	:16	0
11/2/61	19:56	:47	3:17	1	(1) Printer control circuit.	:00	:00	0
11/3/61	19:23	1:59	2:38	1	(1) Drum failure.	:00	:00	0
11/4/61	24:00	:00	:00	0		:00	:00	0
11/5/61	24:00	:00	:00	0		:00	:00	0
11/6/61	19:08	1:05	3:47	1	(1) Drum failure.	:00	:00	0
11/7/61	21:03	:00	2:57	0		:00	:00	0
11/8/61	18:43	1:59	3:18	1	(1) Drum failure.	:00	:00	0
11/9/61	20:06	:29	3:25	1	(1) Power supply, marginal errors.	:00	:00	0
11/10/61	21:24	:00	2:36	0		:00	:00	0
11/11/61	24:00	:00	:00	0		:00	:00	0
11/12/61	22:02	1:58	:00	3	(1)-(2)-(3) Drum failure.	:00	:12	0
11/13/61	20:35	:00	3:25	0		:00	:00	0
11/14/61	20:16	:00	3:44	0		:00	:25	0
11/15/61	20:17	1:07	2:36	2	(1) Printer control circuit. (2) Punch #5 failed.	:00	:28	0
11/16/61	19:45	:47	3:28	2	(1) Drum failure. (2) Input-output eng.	:00	:07	0
11/17/61	21:15	:00	2:45	0		:00	:00	0
11/18/61	22:23	1:37	:00	2	(1) Punch #5 failure. (2) Reader #K, bad light.	:00	:00	0
11/19/61	23:50	:10	:00	1	(1) Punch #5 failed.	:00	:00	0
11/20/61	21:04	:12	2:44	2	(1) Reader D failed. (2) Reader G failed.	:00	:00	0
11/21/61	20:16	:05	3:39	1	(1) Reader D failed.	:00	:00	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
11/22/61	21:08	:24	7:27	1	(1) Punch #5 failed.	:01	:07	0
11/24/61	21:15	:10	2:35	1	(1) Punch #5 failed.	:00	:00	0
11/27/61	17:38	3:28	2:54	5	(1) Memory failure 2^{-27}. (2)-(3)-(4)-(5) Drum failure.	:00	:47	0
11/28/61	20:45	:27	2:48	3	(1) Unknown. (2)-(3) Drum failure.	:00	:22	0
11/29/61	20:24	:00	3:36	0		:00	:03	0
11/30/61	20:31	:00	3:29	0		:00	:00	0
Totals	566:05	16:44	65:10	28		:01	2:47	0

PART V

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New 650 Codes

During the month of November, no new routines were added to the Digital Computer Laboratory 650 Library.

International Business Machines 650 Usage

During the month of November, specifications were presented for 13 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 334'. Numbers followed by T are for theses.

334' Civil Engineering. Soil Classification and Statistical Analysis. The input data consists of per cents of soil grain sizes and Atterberg limits for individual soil samples. By comparison of the given data each soil is classified as one of 12 AASHO soil types and also as one of 15 unified soil types. After classification of N samples, the program computes mean, standard deviation, f variation, standard error, limit of accuracy, mean plus 1.45 standard deviation, coefficient and mean minus 1.45 standard deviation for the Atterberg limits of the N samples. Program will be in SOAP and print out alpha, numeric and alpha-numeric results.

The mathematical method for classification is simply a yes-no comparison of given data until a soil fits into a soil type.

335'T Agronomy. State of Rock Phosphate in Illinois Soils. This research problem involves the testing of soil treatments (that is, no fertilizer treatment, rock phosphorous added, super phosphate and rock phosphate added, only super phosphate added) at depths of 0-6", 7", 8", 9", 10", 11", 12", 13"-24", 25"-36", 37"-48", 49"-60". At each of these depths, the amount of a particular material has been tested for phosphorous, pH, P_1, P_2, potassium, calcium, and others. Analysis of variance will be used to determine if there are different amounts of material present at different depths.

336' Physics. Neutron Resonance Effects in Fissile Materials. Numerical experiments have been performed previously (problem number 273') to find suitable numerical approximations for Doppler-broadened Breit-Wigner neutron cross sections. Such cross sections are needed for a realistic investigation of the temperature effects in chain reacting systems.

The preliminary work (problem number 273') has now reached a stage where a more definitive code has been developed and the purpose of this problem is to investigate the performance of the code, and to obtain preliminary results for cross sections.

337'T Mechanical Engineering. Spherical Bubble Dynamics. This problem involves the solution of finite difference equations in explicit form. The equations describe the collapse of a spherical cavity in an infinite liquid region. Condensation occurs at the inside surface of the cavity. The two main equations are the momentum equation for the liquid and the temperature equation for the liquid.

338' Psychology. Estimation of Number of Factors. The purpose of this investigation is twofold. First, a program obtained from Kansas on a very small problem (the solution to which is already known) is to be tried out. Second, the program (if successful above) will be used in estimates of the number of factors to be extracted in a larger factor analytic study.

In 1959, R. R. Sokal published an article in the Kansas Academy of Science concerning estimation of the number of factors in factor analysis. Sokal's approach was to use a wide variety of estimation methods, and a 650 program was written (1) to extract factors using Thurstone's centroid method and (2) to carry out the various estimation procedures.

339'T Coordinated Science Laboratory. Compensator Optimization. It is desired to minimize a function of four variables. The minimum may be found by solving four simultaneous linear equations. The equations have left hand sides

$$\left.\sum_{L=1}^{4} \sum_{P=1}^{4} \sum_{J=1}^{4} \sum_{I=1}^{8} a_{JIL}\, a_{JIQ}\, A_{JI}\, B_J \right)_{\text{for each } P} C_P\, X_L \quad \text{for } Q = 1, 2, 3, 4,$$

and the constants terms are given by

$$\sum_{P}^{4}\sum_{J}^{4}\sum_{I}^{8} a_{JIQ}\, A_{JI}\, K_J\, B_J \Big)_{\text{for each } P} C_P \qquad Q = 1, 2, 3, 4.$$

The 650 will compute these 20 numbers, then solve the four equations by triangularization and back substitution.

This problem is for finding optimum parameters for the simulation done in Illiac problem specification 2010T.

340' Civil Engineering. Multi-Variant Analysis of Vehicle. To gain an understanding of the relationship between traffic speeds and various roadway and environmental conditions, simple correlation analyses are to be performed for average speed and each of 38 independent variables deemed to have a significant influence on driver speed behavior. Then, values of certain independent variables are to be transformed to log arithmetic, reciprocal, square root, and square scales for additional correlation analysis to gain a better understanding of these relationships.

341' Physics. Least Square Fit in Legendre Polynomials. This is a least-square fit of experimental data on (π^-, P) elastic scattering for five different values of the π^- energy. Library Routine K7'-68' for a least-square fit in Legendre polynomials will be used.

342' Electrical Engineering. Integrated Electron Content of Ionosphere. The problem is to take data from moon reflection experiments and reduce it to integrated electron content. It would involve approximating the earth's magnetic field with a dipole as an alternative to interpolating curves with the computer.

Parts of the program involve calculating elevation and azimuth of the moon for Danville, Illinois, and Belmar, New Jersey; given local time at Danville, Illinois, and given elevation and azimuth of the moon at Danville and Belmar, calculate the quantity $M = H \cos \theta \sec i$, where i is the angle between the plane of sight to the moon and the earth's magnetic field at a certain height and θ is the altitude of the moon. Then, given the average value of M for Danville and Belmar and the change in polarization angle of received signal, calculate the integrated electron content of the ionosphere, from

$$\int_{h_1}^{h_2} N dh = \frac{\Omega f^2}{5.93 \times 10^{-2}\, \overline{M}} .$$

343'T Physical Education. Effect of Ambient Temperature on Endurance Running. The thesis problem undertakes the investigation of the ambient environment and its influence on endurance performances and associated physiological phenomena. A group of seven individuals were exposed to five different temperatures in an environmental chamber on six different occasions and asked to perform a standard load of work. Performance time and specific physiological measures were made at specified times during the environmental exposure.

The experimental design attempts to answer the following questions. Does ambient temperature, expressed as "corrected effective temperature", affect endurance performance? If ambient temperature does have an influence on endurance performance, is it a significant one? If significant, what temperatures differ significantly? To what degree do the associated physiological phenomena reflect the ambient temperature? To what extent are these associated physiological phenomena dependent? Is there some physiological complex that can best predict the length of performance or "breaking point" at the different ambient temperatures?

To answer the questions posed by the experimental design, two basic statistical techniques are employed: an analysis of variance technique to determine the influence of ambient temperature and an intercorrelation matrix to resolve the interaction of the physiological data. This information can be best obtained if the data were put in the statistical form of variance, regression--linear or curvilinear--, and multiregression.

344' Physics. Screened BH-WL. Any experiment with the betatron requires knowledge of the x-ray spectrum given by the machine. This program computes electron-pair production cross sections in various elements using the theory of Bethe and Heitler as modified by Wheeler and Lamb. The cross sections will be used to estimate corrections to the x-ray spectrum required due to x-ray absorption in these elements.

345' Agronomy. Breeding Disease Resistant Field Corn. Resistance to stalk rot and leaf blight is being incorporated into present field corn hybrids as well as new resistant breeding material being developed. Different lines are then tested at two or three locations and analysis of variance used to determine differences among the resistant lines. Experiments are also under way to study the inheritance to both stalk rot and leaf blight. To study the inheritance of the diseases in inbred lines, the original and backcross progeny are grown and their resistance to the disease determined.

346'T Theoretical and Applied Mechanics. Column Analysis. The purpose of this investigation is to study the effect of various parameters on the collapse load of eccentrically loaded columns. A trial and error solution of a set of four non-linear algebraic equations is required.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of November.

TABLE I'

		Hrs:Min	
Scheduled Engineering		11:42	
Unscheduled Engineering		17:14	
Tape Test		2:17	
Computer Operator		1:14	
Log Summary		:27	
Library Development		19:52	
Agronomy Library	3:43		
DCL Library	16:09		
Classes		58:22	
CE 316	1:38		
CE 391	13:10		
CE 497	:08		
EE 342	:14		
EE 388	:31		
MATH 195	37:23		
ME 409	5:18		
Instruction		:24	
Wasted		6:53	
			118:25

Use by Departments

Agronomy	10:25
Animal Science	12:46
Chemistry	8:27
Civil Engineering	6:20
Coordinated Science Laboratory	2:08
Electrical Engineering	10:23
Food Technology	2:31
Graduate College	5:27
IREC	:29
Mechanical Engineering	3:10
Mining and Metallurgical Engineering	1:20
Physics	10:41

Small Homes Council		:31		
State Water Survey		6:33		
Statistical Service Unit		155:36		
Agricultural Economics	3:28			
Agricultural Extension	2:09			
Bur. Community Planning	10:01			
Bur. Educational Research	4:40			
Bursar's Office	8:30			
Business Office	78:04			
DHIA	45:59			
Education	2:35			
Statistical Service Unit	:10			
Theoretical and Applied Mechanics		1:39		
			238:26	
				356:51

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for November.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

533 card read punch		1
Card jam	1	
727 and 652 tape units and tape control		3
Read validity checking error	2	
Reads and writes tape incorrectly	1	
407 accounting machine		4
Card jams	2	
Fails to read cards	2	
650 console and magnetic drum unit		3
Lost bits	2	
Multiple bits	1	
	TOTAL	11

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
11/1/61	17:53		(2:00)* :02	:16	1	(1) Card jam in 407. Latch needed adjustment.
11/2/61	17:41			:21	0	
11/3/61	13:26		1:25	1:24	2	(1)-(2) Read validity checking error on tapes.
11/6/61	11:51	4:01		:05	0	
11/7/61	16:11			:22	0	
11/8/61	17:46			:54	0	
11/9/61	5:58		12:23	:12	1	(1) Would not read or write tape correctly. Bad tube found in IAS.
11/10/61	14:36		3:19	:10	1	(1) Lost binary bits in accumulators. Would not reset to 0. Bad tube unit found.
11/13/61	13:35	2:32		:00	0	
11/14/61	15:39			:17	1	(1) Lost bit in position 3 of program register.
11/15/61	16:47			:09	0	
11/16/61	16:11			:14	0	
11/17/61	16:46			:34	0	
11/20/61	15:07	1:15		:03	1	(1) Card jams in 407. Found a bad latch operating arm.
11/21/61	15:54			:11	0	
11/22/61	15:56			:14	1	(1) 407 would not read cards off line.
11/24/61	15:57			:05	1	(1) 407 would not read cards off line.
11/27/61	11:20	3:54		:43	0	
11/28/61	15:50			:07	0	
11/29/61	16:17		:05	:14	2	(1) Double bits in pos. 5 of distributor twice. (2) Card jam in 533 punch.
11/30/61	20:21			:18	0	
TOTALS	321:02	11:42	17:14	6:53	11	

PART VI

INSTRUCTIONAL USE OF COMPUTERS

During the month of November, specifications were presented for 11 new problems.

12 Mathematics 195. Problem 4. IBM 650. Surface Area of Triangles. A plant manufactures triangular steel plates of various sizes which must be painted. You are to write a program which will compute the paint cost for batches of these plates.

The lengths of the sizes of the triangle in inches are being represented by the letters a, b and c. All plates are 0.5 inches thick. The paint cost is $8.50 per gallon, and one gallon covers 1,000 square feet.

The data is to be read by the program from data cards. Each data card has the following five numbers punched on it.

a: cols. 1-10, floating-point value in inches.
b: cols. 11-20, " " " " "
c: cols. 21-30, " " " " "
N: cols. 31-40, the number of plates having the dimensions punched in cols. 1-30, in fixed-point form.
I: cols. 41-50, the identification number of this batch of plates, in fixed-point form.

An asterisk is punched in col. 75. Use the following assignment of GAT variables.

$$a \equiv X1$$
$$b \equiv X2$$
$$c \equiv X3$$
$$N \equiv I1$$
$$I \equiv I2$$

Print the cost (in dollars) of painting (top, bottom and edges) the batch of N plates; use GAT variable Y1 to represent this cost. With the cost, print the identification number (GAT variable I2). There will be an arbitrary number of data cards so your program should end on a READ statement.

Make up your own data cards (not more than ten) for testing your program.

To be counted correct, your program must produce correct results for our data. We will allow an error of $.05 but no more than this.

See "Mathematical Tables from Handbook of Chemistry and Physics" or similar tables for the required formulas; or derive them yourself.

13 Civil Engineering 497. Problem 1. IBM 650. Allocation and Scheduling of Construction Equipment. The problem of optimum allocation of construction equipment to a highway construction project is to be solved by the linear programming methods.

The problem of optimum scheduling of the construction operation is to be solved using critical path and linear programming methods.

14 Mechanical Engineering 406. Problem 1. ILLIAC. Temperature Distribution. A set of linear equations has to be solved by use of library routine L7.

15 Mathematics 295. Problem 2. ILLIAC. Matrix Multiplication. Write a program to compute C = AB where A and B, and hence C, are square, m x m, matrices with $1 < m \leq 8$.

Let c_{ij} be the element in the i^{th} row and j^{th} column of the matrix C, a_{ij} and b_{ij} being similarly defined for the matrices A and B, then

$$c_{ij} = \sum_{k=1}^{m} a_{ik} b_{kj}$$

The elements of the matrix A, a_{ij}, and the matrix B, b_{ij}, are to be read from a data tape using the ILLIAC library input routine N12. The format of the data tape is as shown below.

$$\begin{array}{lllll}
a_{11} & a_{12} & a_{13} & \cdots & a_{1m}\ \mathrm{N} \\
a_{21} & a_{22} & a_{23} & \cdots & a_{2m}\ \mathrm{N} \\
a_{31} & a_{32} & a_{33} & \cdots & a_{3m}\ \mathrm{N} \\
\cdot & & & & \cdot \\
\cdot & & & & \cdot \\
\cdot & & & & \cdot \\
a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mm}\ \mathrm{NJ} \\
b_{11} & b_{12} & b_{13} & \cdots & b_{1m}\ \mathrm{N}
\end{array}$$

(continued)

$$
\begin{array}{cccccc}
b_{21} & b_{22} & b_{23} & \cdots & b_{2m} & N \\
b_{31} & b_{32} & b_{33} & \cdots & b_{3m} & N \\
\cdot & & & & \cdot & \\
\cdot & & & & \cdot & \\
\cdot & & & & \cdot & \\
b_{m1} & b_{m2} & b_{m3} & \cdots & b_{mm} & NJ
\end{array}
$$

where a_{ij} and b_{ij} are signed, decimal fractions.

The elements of the matrix C, c_{ij}, which are to be computed by your program, are to be printed by the ILLIAC library routine P16. The format of the output is to be as shown below.

I	J	C
1	1	__________
1	2	__________
.	.	.
.	.	.
.	.	.
1	m	__________
2	1	__________
2	2	__________
.	.	.
.	.	.
.	.	.
2	m	__________
.	.	.
.	.	.
.	.	.
m	1	__________
m	2	__________
.	.	.
.	.	.
.	.	.
m	m	__________

Thus, in the first column the index i is to be printed. In the second column the index j is to be printed. These indices are to be printed <u>without</u> sign. In the third column the elements of C are to be printed as signed 12 digit decimal fractions.

It will be necessary for your program to determine the size of the matrix, i. e., m. This information will be contained in the left hand address of the 21st word of subroutine N12 following read-in of the data; see the write-up of this subroutine.

Your program is to be written in such a way that after the final stop, OF, a skip (white switch) start will begin the computation

$$C' = A'B'$$

again, where A' and B' are a new pair of matrices. When this new computation is made a new set of column headings should be printed. Consequently, you will find it most convenient if you use 92 orders to label the columns.

Your name and course number is to appear once at the front of the output. Hence, the "J" facility can be used.

For convenience in checking numerical accuracy, the matrices A and B have been chosen so that the off-diagonal elements of C are zero. You will not be able to get exactly zero for these terms no matter how careful you are since the input data, a_{ij} and b_{ij} will not be exact. However, your off-diagonal elements should be small, and should not exceed 10^{-11}.

16 Mathematics 295. Problem 3. ILLIAC. Factoring of Integers. All numbers involved are positive integers. If x divides y exactly, leaving a zero remainder, x is called a <u>divisor</u> of y. A <u>prime</u> p is an integer such as 2, 3, 5, 7, 11, 13, 17 ... which

(a) is not equal to 1, and

(b) has no divisors except itself and 1.

Any integer can be expressed as the product of its prime divisors. For example,

$60 = 2 \cdot 2 \cdot 3 \cdot 5$ (composite)

$127 = 127$ (prime)

This factorization is unique (except, of course, for rearrangements of the order of the prime divisors).

Except for 2, all primes are odd numbers. A composite number is the product of at least two primes which cannot both be greater than its square root. Therefore, we can factor a number by removing factors of 2 and trying all odd numbers (hence all primes) which are less than its square root. If the integer is negative it can be regarded as having a factor (-1). Then the positive result can be factored as usual.

Example   Factor 1204.

Since 1204 is even, it has a factor of 2. $1204 = 2 \cdot 602$

Since 602 is even, it has a factor of 2. $602 = 2 \cdot 301$

Since 301 is odd, there are no more factors of 2.

3 does not divide 301.

5 does not divide 301.

7 divides 301, 43 times. $301 = 7 \cdot 43$

But since $7 > \sqrt{43}$, we know that 43 is a prime.

Hence, $1204 = 2 \cdot 2 \cdot 7 \cdot 43$.

To avoid having to take a square root, we may stop when a trial division gives a non-zero remainder, and the quotient is less than or equal to the divisor.

Write a program which will cause Illiac to print your name and course and a title for the problem, and then input your program and stop. A data tape containing a sequence of integers to be factored is then placed in the photoelectric tape reader, and the black switch (optional stop disable) is pressed. Your program should cause the data to be read in, and each number should be printed together followed by its factorization. Code check this routine using the data tape which the computer operator will have.

The data tape is in N12 format; each signed integer is followed by N; the sequence is followed by J, i. e.,

(integer) N, (integer) N, ..., (integer) N J.

17   Physics 341. Problem 1. IBM 650. Comparison of an Experimental and Theoretical Study of Alternating Current Circuits. The purpose of this problem is to compare an experimental and theoretical study of the following alternating current circuits: a series RLC circuit, a parallel RLC circuit, and a circuit that contains a parallel T null network.

The problem consists of simple calculations which are to be repeated many times. As an example, the current in a series RLC circuit is to be computed as a function of frequency.

18 Mechanical Engineering 342. Problem 1. ILLIAC. Polynomial Solution of Cam Curves. Illiac is to be used to solve six simultaneous linear equations for five different boundary conditions. These coefficients will then be used to calculate 20 points on the following curves.

1. Displacement
   $y = f(\theta)$

2. Velocity
   $y = f'(\theta)$

3. Acceleration
   $y = f''(\theta)$

A set of curves is to be calculated for each boundary condition using the IBM 650.

The equations to be solved are of the form

$$0 = A + A_0C_1 + A_1C_2 + A_2C_3 + A_3C_4 + A_4C_5 + A_5C_6$$

where

A's = constants

C's = unknown coefficients.

19 Mechanical Engineering 342. Problem 1. IBM 650. Polynomial Solution of Cam Curves. The IBM 650 is to be used to calculate 20 points on the following curves:

$$y = C + C_1 \left(\frac{\theta}{\beta}\right) + C_2 \left(\frac{\theta}{\beta}\right)^2 + C_3 \left(\frac{\theta}{\beta}\right)^3 + \ldots. + C_9 \left(\frac{\theta}{\beta}\right)^9$$

$$\text{Velocity} = y' = C_1 + 2C_2 \left(\frac{\theta}{\beta}\right) + \ldots.9C_9 \left(\frac{\theta}{\beta}\right)^8$$

$$\text{Acceleration} = y'' = 2C_2 + \ldots. + 72C_9 \left(\frac{\theta}{\beta}\right)^7$$

$\frac{\theta}{\beta}$ varies from $0 \rightarrow 1$.

The coefficients $C_1 - C_9$ will be evaluated on the Illiac.

Five different boundary conditions have been set. Therefore, five sets of curves will be calculated. These polynomial curves are being used in an effort to obtain a more desirable acceleration curve in a cam.

20 Mathematics 195. Problem 5. IBM 650. Problems in the Approximation of Functions. Given the recurrence relation

$$P_0 = 1, \; P_1 = x$$

$$(i + 1)\, P_{i+1} - (2\, i + 1)\, x\, P_i + i\, P_{i-1} = 0$$

derive the formula for P_6 as a function of x, by generating successively P_2, P_3, P_4, P_5 and finally P_6.

Expand cos x in a Taylor series about $x = \frac{\pi}{4}$ up to and including the term involving the fourth derivatives of cos x. Give the expression for the remainder R_4. Make a table of this approximation of cos x and the upper bound for the remainder for $x = 0^\circ\ (2^\circ)\ 90^\circ$. Use the IBM 650 for this calculation. Print three columns:

x (in degrees)	sin x	max $\lvert R_4 \rvert$

Compare your results against the values in the table (to be posted). What is the size of the error in your approximation when

$$x = 0^\circ,\ 10^\circ,\ 20^\circ,\ 30^\circ,\ 40^\circ,\ 50^\circ,\ 60^\circ,\ 70^\circ,\ 80^\circ,\ 90^\circ.$$

Are these errors consistent with your estimate of the upper bound for the remainder? If they are not consistent, explain why. The following constant will be useful.

$$\sin \frac{\pi}{4} = \cos \frac{\pi}{4} = 0.70710\ 67812$$

Expand arc sin x about x = 0.70710 67812 in a Taylor series up to and including the fourth order term (i. e., the term involving the fourth derivative of arc sin x). Give the expression for the remainder R_4. What happens to this expansion when x becomes equal to 1?

Using the fourth order expansion as an approximation for arc sin x, make a table of arc sin x and the upper bound for R_4 for x = 0 (0.05) 0.9. Use the IBM 650 for this calculation. Print three columns:

x	arc sin x (in radians)	max $\lvert R_4 \rvert$

Compare your results against the values in the table (to be posted). What is the size of the error in your approximation when

$$x = 0,\ 0.2,\ 0.7,\ 0.9.$$

Are these errors consistent with your estimate of the upper bound for the remainder? If they are not consistent, explain why.

Using the posted values for cos x at $x = 0^\circ, 10^\circ, 20^\circ, 30^\circ, 40^\circ$, give the fourth degree polynomial approximation (LaGrange interpolation formula) for $0^\circ \leq x \leq 40^\circ$. Prepare a table of cos x for $x = 0^\circ\ (2^\circ)\ 40^\circ$ using this approximation. Use the IBM 650. Print two columns:

<u>x degrees</u>	<u>cos x</u>

How do the values in this table compare with those in the earlier table?

21 Electrical Engineering 388. Problem 1. IBM 650. Data Plotter Test-GAT. $y = x^3$ for $x = -10.(+.1) + 10$ will be computed. The output of the data plotter program is in a form so that one pass through the card-to-tape converter will yield a tape in the data plotter format. The purpose of this is to gain experience with and test the data plotter routine.

22 Civil Engineering 391. Problem 2. IBM 650. Computation of Total Stiffnesses and Fixed-End Moments. This is the second of three interconnected problems, and serves principally as a tie between problem 1 and 3. However, the following new ideas are introduced:

a. Use of subroutine linkages.
b. Address modification and logical decisions based on input quantities.
c. SOAP programming.
d. Choice of suitable scale factors.

A typical continuous beam structure will be treated. As a second step in the moment-distribution procedure, the fixed-end moments and relative stiffnesses at each end of each member must be computed. This assignment consists of writing a program to obtain the fixed-end moments due to a series of concentrated loads, and to store the fixed-end moments and relative stiffnesses for Problem Number 3, which will perform the actual moment distribution.

PART VII

GENERAL LABORATORY INFORMATION

Seminars

"A Compiler for ILLIAC," by Mr. Ross Flenner, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, November 6, 1961

"Experiments in the Numerical Evaluation of Certain Wiener Integrals," by Professor L. D. Fosdick, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, November 13, 1961.

"Organizational Problems of Large Computing Systems," by Dr. Sullivan G. Campbell, Manager of Advanced System Programming, IBM Corporation, Poughkeepsie, New York, November 20, 1961.

"Machine Construction of Proofs of Theorems in Euclidean Geometry," by Dr. Herbert L. Gelernter, IBM Research Center, Yorktown Heights, New York, November 27, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	12	1	12.5
Research Associates	8	0	8.0
Graduate Research Assistants	11	19	21.1
Graduate Teaching Assistants	0	3	1.5
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	39	14	45.95
TOTAL	77	37	95.05

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

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PART VII - GENERAL LABORATORY INFORMATION

December, 1961

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1) 415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1) 415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Construction Progress

Table I summarizes the progress during the month toward completion of the computer. Entries in Table I indicate the number of transistors which have completely passed through the phase of design or construction indicated by the column heading. Within one rectangle of Table I, the three figures from top to bottom indicate completions, respectively, at the beginning of the month, during the month, and at the end of the month. The transistor counts are intended to reflect the amount of work directly applicable toward completion of the computer, rather than total effort expended. For example, if the wiring of a chassis has to be modified, it is removed from the "completed" list, and indicated as having been wired again during the month in which the modification is made.

Completion of systems design indicates that the general strategy of design has been worked out in some detail. For a control, for example, a mnemonic order code would be fixed on completion of systems design, although the numerical equivalents for each order would be unknown. Logical design completion would be indicated by a logical diagram in which circuit restrictuions on fanout and cascading are observed, but physical distances and consequent cable driver circuits are not included.

Physical placement is completed when chassis boundaries are fixed, and cable driving circuits included in the logical diagram. In block layout, the function of each transistor on a chassis is indicated by circuit block symbols. Information sufficient for drafting, frame wiring, component layout, and power supply requirements is available on completion of block layout.

Component layout requires as many as 14 drawings for each chassis, showing successive phases of wiring of the chassis.

The static test involves application of D.C. power to the chassis before transistors are plugged into sockets. Voltage measurements at all nodes indicate faulty components, wiring errors, etc., not caught during visual inspections.

TABLE I

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Drafting	Subsystems Test	System Test
Repetitive M.A.U. 5379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	
Core Storage Unit (4096 words) 3883	3,883	3,883	3,883	3,883	3,883	3,883	3,883	3,883	2,150		
Delayed Control, EAU and End Connections 10,288	10,288	10,288	10,288	7,484 1,344 8,828	5,004 2,072 7,076	4,224 986 5,210	2,843 1,457 4,300	1,652 1,875 3,527	1,025	0 1,198 1,198	
Flow Gating (Buffer Storage) 3987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,842	2,326 1,383 3,709	
Advanced Control 7000	6,040	5,500 300 5,800	1,950	0	0	0	0	0			
Drum Storage Unit 2500	2,500	800 300 1,100	0					0			
Interplay Control 3000	3,000	1,000 2,000 3,000	0 500 500	0				0			
Paper Tape Input-Output 641	641	641	641	641	641	641	641	189 452 641			
Test Controls	1,434	1,434	1,434	1,434	1,434	1,259 175 1,434	1,259 175 1,434	1,044 215 1,259	438	671 0 671	
TOTALS	37,152	32,912 2,600 35,512	27,562 500 28,062	22,808 1,344 24,152	20,328 2,072 22,400	19,373 1,161 20,534	17,992 1,632 19,624	16,134 2,542 18,676	12,835	8,376 2,581 10,957	

TABLE II MALFUNCTIONS FOUND DURING DECEMBER

	Open Connection or Bad Solder Joint	Faulty Transistor Pin	Missing Component; Wiring Error	Open Resistor	Shorted Capacitor	Faulty Diode or Zener Diode	Faulty Transistor	Faulty Indicator Bulb	Totals
Non-repetitive Arithmetic Unit	21	7	9	1		1		2	41
Repetitive Arithmetic Unit					1		1	2	4
Flow Gating Buffer Storage	1			1		1			3
Test Controls	3								3
Totals	25	7	9	2	1	2	1	4	51

The column headed drafting indicates the completion of circuit schematics only. Thus, considerable drafting effort, such as preparation of logical drawings, figures for reports, etc., is not reflected in Table I.

A subsystems test is a dynamic test of several thousand transistors using a relatively simple fixed program usually generated by a small special purpose control to be discarded later. Systems tests can occur when sufficient equipment is assembled to run programs read from punched tape.

2. Subsystems Tests

Early in the month, the second error free run including all previously untested chassis of the flow-gating buffer storage unit was completed. (For further details, see the November, 1961, Technical Progress Report.) During the month, eight more digits were added to the main arithmetic unit, employing the non-repetitive chassis containing bits 1 to 4 and 41 to 44 of the registers. Malfunctions found are summarized in Table II. The unit was operated 408.7 hours during the month, concluding with an error free run in excess of 51.7 hours over the New Year's weekend.

3. Core Memory

Testing of the memory was continuing at the beginning of the month. Several problems were evident after a few days of study:

(1) Noise from the Y-drivers was causing an intolerable signal-to-noise ratio on bit numbers 0-5. This noise, which partially overlaps the signals, was due to magnetic coupling to the digit-sense wires and had been observed in previous tests. Previously, however, it could not be established whether the noise would or would not cause erroneous operation. (In the full scale memory, a total of only 10-20 bits were solidly erroneous and, then, only with a reversing pattern running.) After trying several ideas for combatting this problem, it was decided to rewire the Y-drive lines of 2048 words in a magnetic cancellation configuration ("twisting"). This was begun on December 27.

(2) Under worst conditions of heating, the amplitude of some sense signals is below the design minimum allowed for the amplifiers (design minimum, 37 mv; worst signal, 25-30 mv). If the noise is sufficiently reduced, it will be possible to increase the amplifier gain and solve this problem. It should be noted, also, that the unforeseen problem in this case is that the stack construction does not allow air flow over the magnetic switches in the volume originally planned.

(3) The noise trailing the cycle has longer settling time than in the model. This seems to be due to (a) the fact that 13 1/2 times as much energy is delivered to the digit lines in the full-scale memory as compared to the model and (b) the digit lines, as noted many times before, have a characteristic impedance which is too high to be properly matched. A (theoretically) simple rearrangement of the digit lines would undoubtedly reduce this problem a great deal. However, rearrangement of the present core stack is difficult. This situation will probably limit the cycle time with the present core stack to about 1.8 μs.

(S. Ray)

4. Magnetic Drum Memory

The first 32,768 word magnetic drum arrived from Vermont Research Corporation on December 14. It was shipped by air and motor freight, double boxed, apparently without damage.

Prior to shipment, the heads were all retracted from the drum. After arrival the 16 heads in column P were advanced to produce a specified output (56 millivolts peak to peak). During this adjustment it was found that there was a small change of read voltage as the drum warmed up. In the heat runs taken so far this increase has amounted to 2 to 7 millivolts with most of the increase occurring in the first two or three hours. Relative to the other phenomena which affect signal amplitude this is a moderate change.

Some preliminary data was taken on amplitude modulation, noise, and resolution (high frequency response). All appear to be approximately as specified in File 332. These measurements were very preliminary; all will be repeated in more detail after our measurement techniques have been refined.

(H. C. Brearley)

During the month two reports were published. They were "Bit Clock Pulse Checking Circuit for the Magnetic Drum Memory," File 420, December 11, 1961, and "Peak Detection Circuit for the Magnetic Drum Memory," File 421, December 12, 1961. The manuscript of "Description of the Logical Circuits for the Magnetic Drum Memory," which will appear as File 419, was turned over to the typists.

The new experimental peak detector was operated with the magnetic disk. It worked fairly well. After the drum arrived it was operated with the drum and did not work as well at the higher bit rate. The trouble seems to be in the

read amplifier which was used to drive the peak detector. It appears to have both inadequate high frequency and low frequency response, but which parts of the read amplifier circuit are responsible has not yet been determined.

(M. Falleni)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1845(15).)

1. Introduction

Tohru Moto-Oka pursued his studies of tunnel-diode circuits, especially in view of optimizing the cleanness of signals by better impedance adaptation. Together with Henry Guckel a study of a new kind of transformer, formed of two striplines, one inside the other, was started. This kind of transformer shows great promise in the KMC range. A more detailed description will appear in next month's report. Henry Guckel also investigated a simple high-speed counter using npn and pnp units in combination; details will be found below.

John Hill came out with a practical solution to the dc-drift indicator problem that occurs in failsafe emitter-follower circuitry described two months ago. He also designed a dynamic flipflop to go with his system. Circuit diagrams are discussed in Section 3.

Sergio Ribeiro discovered that the previous theory does not explain supersaturation. As shown below it leads to an expression for the gain which is always less than one. A new theory, based on the Early Effect, is being tried. Assuming that Shockley's equations are valid into saturation, the equivalent circuit parameters were calculated and then approximated in the region above supersaturation.

Thomas Burnside continued his work on the probability analysis of circuits. Plans are being made to build some hardware to try out theoretical results. Some preliminary thoughts were given to such a system.

2. Fast npn-pnp Counter

The transistorized section of a high speed counter was designed with emphasis on simplicity and economy. The circuits will be put on printed circuit boards to facilitate ease of duplication. The topology used on a single board is shown in Figure 1. Read-out circuits will use the Amperex Z550M decade numerical indicator. A model of a scale of six counter has been built and is being evaluated.

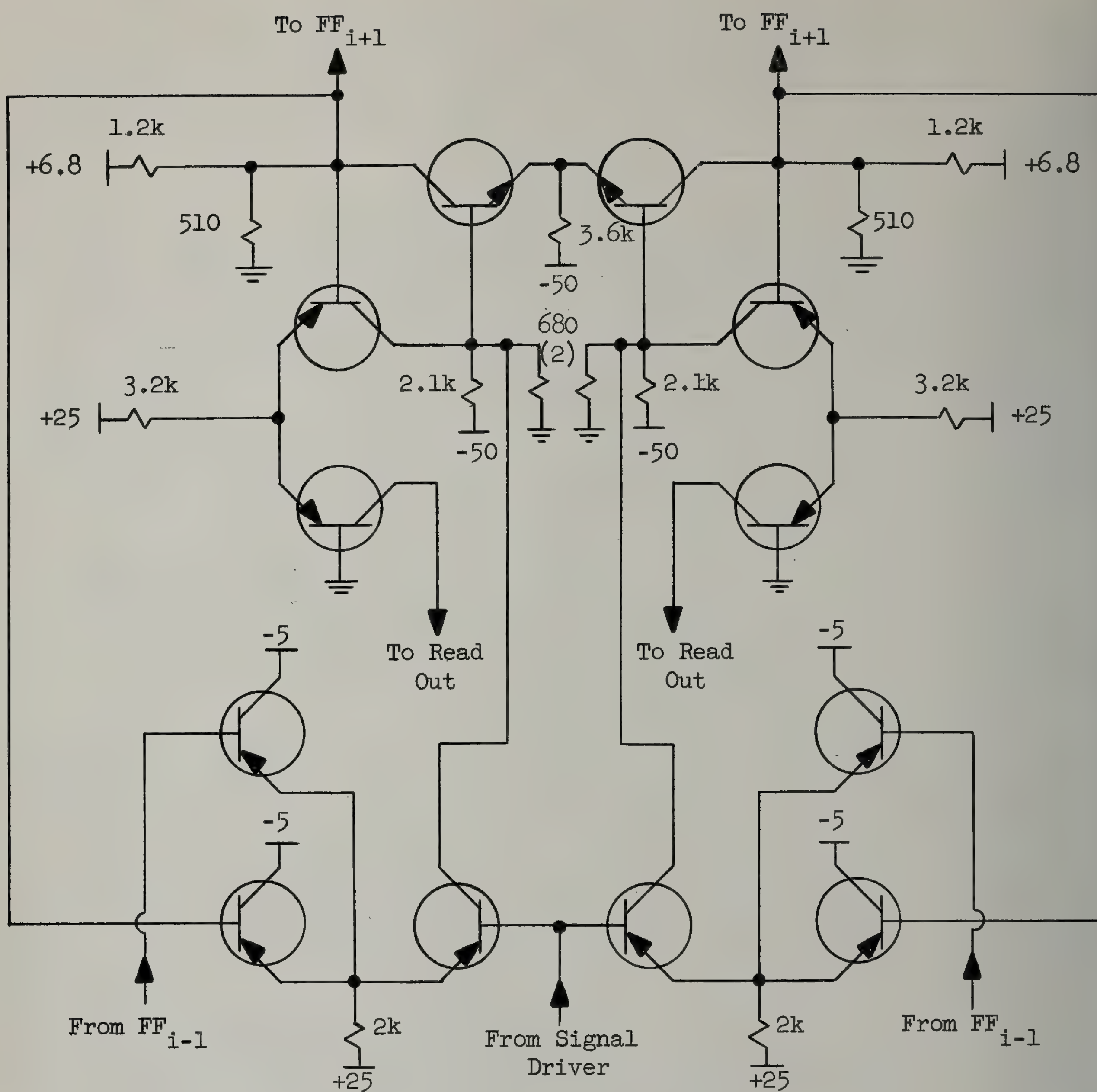
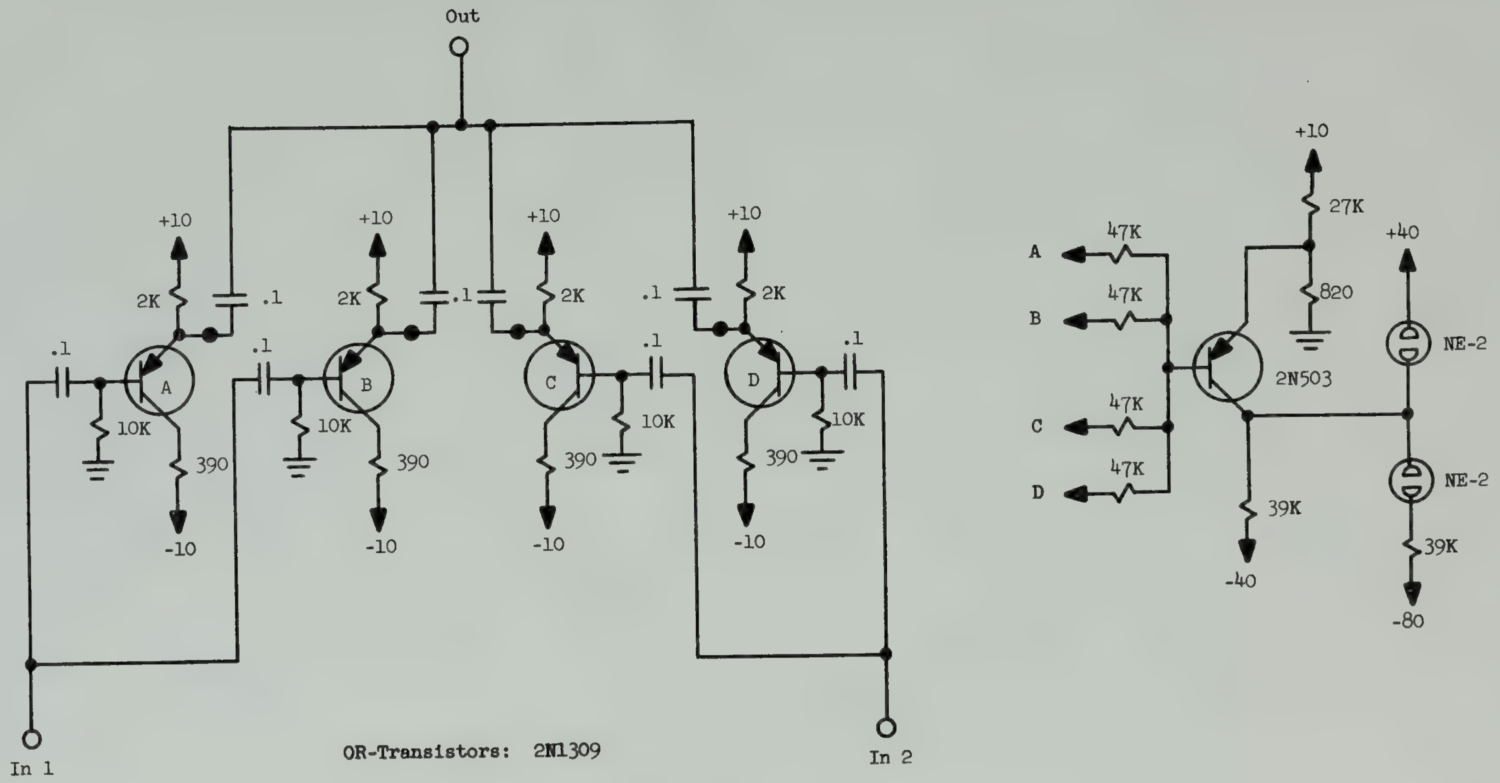


Figure 1 Stage of an npn-pnp Counter

Figure 2 Indicating Failsafe OR Circuit



3. Failsafe Circuits

An efficient failure indicator has been designed to continuously monitor the D. C. operating points of transistors in failsafe circuits. The circuit is a one transistor linear amplifier with four inputs and an output in the form on a neon indicator.

Summing resistors are attached to the emitter of the transistors in the failsafe circuits. As explained in a previous report, when any trouble occurs in any individual transistor, its emitter voltage changes. This change as transmitted to the summing junction, is amplified linearly, and fires one of the two biased neon bulbs in the collector circuit. Even if the failure should only be intermittent, a neon bulb will remain lit because it has a relatively small sustaining potential. This failure monitor possesses another necessary feature: if anything goes wrong with the monitor transistor, the indicator lights, too. This type of failsafe pulse circuit with its monitor has only 2 1/2 times as many transistors as ordinary logic circuits. Figure 2 shows the actual circuit values that were used.

An A. C. flip-flop has been designed for use with the A. C. coupled failsafe logic circuits. Now a complete set of failsafe circuits (AND, OR, NOT and flip-flop exists. The flip-flop is a straightforward dynamic type and is illustrated in Figure 3. It is built around an AND-OR combination

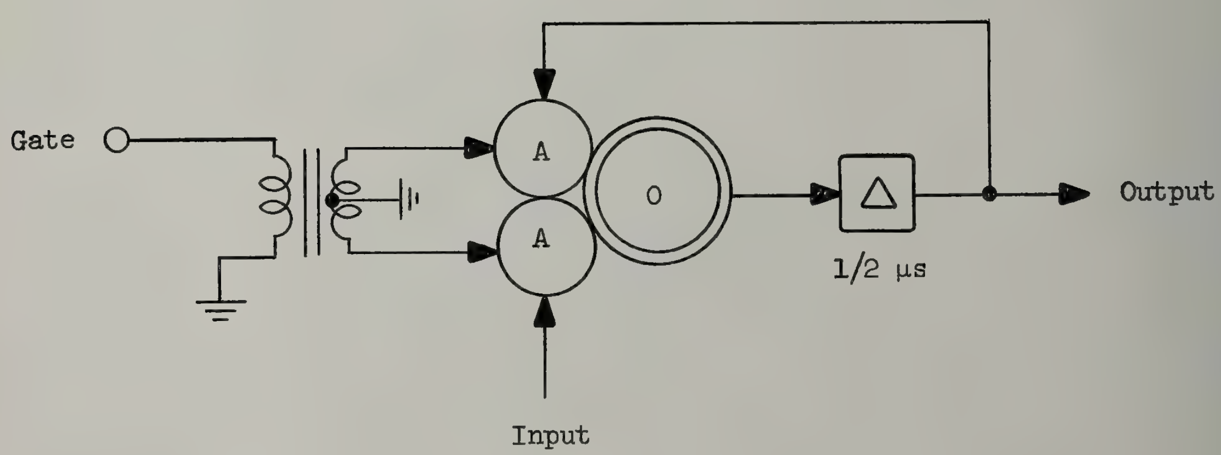


Figure 3 Dynamic Flip-flop

and a multiple segment L-C delay line. When a positive or a negative pulse is set into the flip-flop, the pulse continues to circulate and is restored by the gating pulse at each clock period. The output appears one clock period later.

4. Saturating Transistors

A. Supersaturation

An error was found in the derivation of the tentative equation for G_I, which was obtained by simplified physical assumptions. The correct result is

$$G_I = - \frac{1}{\left(\frac{R_E}{\rho}\frac{w}{L_p} + 1\right) + S\tau_p \frac{R_E}{\rho}\frac{w}{L_p}}$$

where R_E and ρ are as defined, w is the base width, and L_p is the diffusion length of holes in the base.

This result has been checked by a more exact solution of the diffusion equation, and using the assumption

$$\left| \xi \frac{w}{L_p} \right| \ll 1 \text{ , where } \xi = \sqrt{\frac{\delta+1}{2}} + j\sqrt{\frac{\delta-1}{2}} \text{ , } \delta = +\sqrt{1+w^2\tau_p^2} \text{ , } \begin{cases} w = \text{frequency} \\ \tau_p = \text{lifetime} \end{cases}$$

Since this assumption is practically a standard one (recalling our frequencies are of the order of 1 kc/sec), we are led into the conclusion that standard assumptions and procedures will not explain the phenomenon.

In fact, our theoretical equation is of the form:

$$G_I = - \frac{1}{(\gamma + 1) + S\tau_p\gamma}$$

while our experimental results are of the form:

$$G_I = \frac{1}{(\gamma - 1) + S\tau\gamma} \text{ ,}$$

where τ is some time constant and γ is some parameter dependent on the biasing conditions and obtaining values around <u>one</u>.

An attempt is being made to explain the phenomenon at least qualitatively, by the Early Effect.

B. Normal Saturation

A solution of the diffusion equation in the base, emitter and collector (all for the one dimension case), furnishes the y parameters:

$$y_{11} = +\xi \left(\frac{1}{\rho_{Ep}} \coth\left[\xi \frac{w}{L_p}\right] + \frac{1}{\rho_{En}} \right) \qquad y_{12} = -\xi \frac{1}{\rho_{cp}} \operatorname{csch}\left[\xi \frac{w}{L_p}\right]$$

$$y_{21} = -\xi \frac{1}{\rho_{Ep}} \operatorname{csch}\left[\xi \frac{w}{L_p}\right] \qquad y_{22} = +\xi \left(\frac{1}{\rho_{cp}} \coth\left[\xi \frac{w}{L_p}\right] + \frac{1}{\rho_{cn}} \right)$$

where ξ has been defined in the previous section and

ρ_{Ep} = theoretical dynamic resistance of emitter junction for holes, calculated for the isolated junction from Shockley's pn junction theory.

ρ_{En} = " for electrons

ρ_{cp} = " collector junction, for holes

ρ_{cn} = " collector junction, for electrons

If we neglect electron conduction from the base into emitter and collector, and take account of emitter base and collector bulk resistances, respectively r_E^o, r_f^o, r_c^o, the following expressions are obtained for the equivalent circuit parameters of Figure 4.

$$\mathfrak{z}_E = \rho_{Ep} \frac{\cosh\left[\xi \frac{w}{L_p}\right] - 1}{\xi \sinh\left[\xi \frac{w}{L_p}\right]} + r_E^o$$

$$\mathfrak{z}_B = \rho_{Ep} \frac{1}{\xi \sinh\left[\xi \frac{w}{L_p}\right]} + r_B^o$$

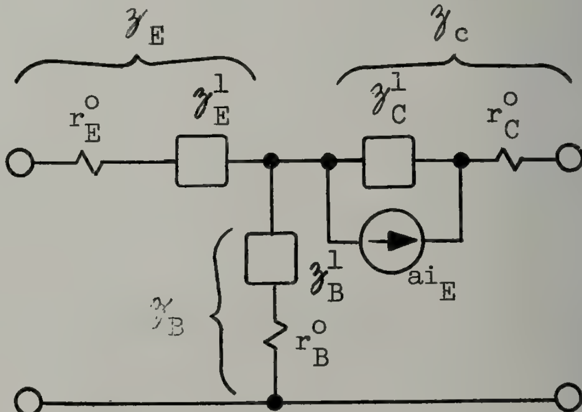


Figure 4 Equivalent Circuit in Saturation

$$\mathcal{z}_c = \frac{\rho_{cp} \cosh\left[\xi \frac{w}{L_p}\right] - \rho_{Ep}}{\xi \sinh\left[\xi \frac{w}{L_p}\right]} + r_c^o$$

$$a = \frac{\rho_{cp} - \rho_{Ep}}{\rho_{cp} \cosh\left[\xi \frac{w}{L_p}\right] - \rho_{Ep}}$$

As a first approximation, these results can be put in the form:

$$\mathcal{z}_E = \rho_{Ep} \frac{w}{2L_p} + r_E^o \quad ; \quad \mathcal{z}_B = \rho_{Ep} \frac{w/L_p}{1+jw\tau_p} + r_B^o$$

$$\mathcal{z}_C = \frac{(\rho_{cp} - \rho_{Ep}) \; L_p/w}{1 + jw\tau_p} + \rho_{cp} \frac{w}{L_p} + r_c^o \quad ; \quad a = \frac{\rho_{cp} - \rho_{Ep}}{\rho_{cp}\left\{1 + \frac{w^2}{2L_p^2}(1+jw\tau_p)\right\} - \rho_{Ep}}$$

Neglecting $\frac{w}{L_p}$ in comparison with $\frac{L_p}{w}$ in the expression for $\mathcal{z}_c$ and assuming $w\tau_p \ll 1$, we get the low frequency results:

$$\mathcal{z}_c = (\rho_{cp} - \rho_{Ep}) \frac{L_p}{w} + r_c^o \qquad a = \frac{\rho_{cp} - \rho_{Ep}}{\rho_{cp}\left[1 + \frac{1}{2}\left(\frac{w}{L_p}\right)^2\right] - \rho_{Ep}}$$

The impedance across current source "a" is visibly

$$\mathcal{z}'_c = (\rho_{cp} - \rho_{Ep}) \frac{L_p}{w} ;$$

Then $$a = \frac{\mathcal{z}_c^1 \frac{w}{L_p}}{\mathcal{z}_c^1 \frac{w}{L_p} + \rho_{cp} \frac{w^2}{2L_p^2}} = \frac{\mathcal{z}_c^1}{\mathcal{z}_c^1 + \rho_{cp} \frac{w}{2L_p}} = \frac{1}{1 + \frac{1}{2} \frac{\rho_{cp}}{\mathcal{z}_c^1} \frac{w}{L_p}}$$

$$\text{i.e.} \quad a \approx 1 - \frac{1}{2}\,\frac{W}{L_p}\,\frac{\rho_{cp}}{\mathfrak{z}_c^1}$$

It is clear that $\mathfrak{z}_c^1$ will have to drop by orders of magnitude before "a" starts to drop by a few percent, and that the decrease of "a" only becomes large when $\mathfrak{z}_c^1$ approaches zero, i.e., when $\mathfrak{z}_c$ approaches r_c^o, the collector bulk resistance. This is entirely in accord with the available experimental data obtained from measurements of y parameters on GF-45011 transistors.

We can then say that the parameter more responsible for the degeneration of transistor characteristics with saturation is $\mathfrak{z}_c$; its junction and base component $\mathfrak{z}_c^1$ short-circuits the current source "a", which is <u>even at fairly deep saturation levels</u> quite able to perform its function.

5. <u>Probabilistic Circuit Analysis</u>

It was decided to build a system in hardware which essentially corresponds to the diode problem brought up in last month's report. One of the problems is to design a "sampling switch" which connects a certain number of representative diodes into the circuit, the output being analyzed by a spectrum analyzer. It is thought that switches of the bridge-modulator gate type (see Figure 5) might be suitable.

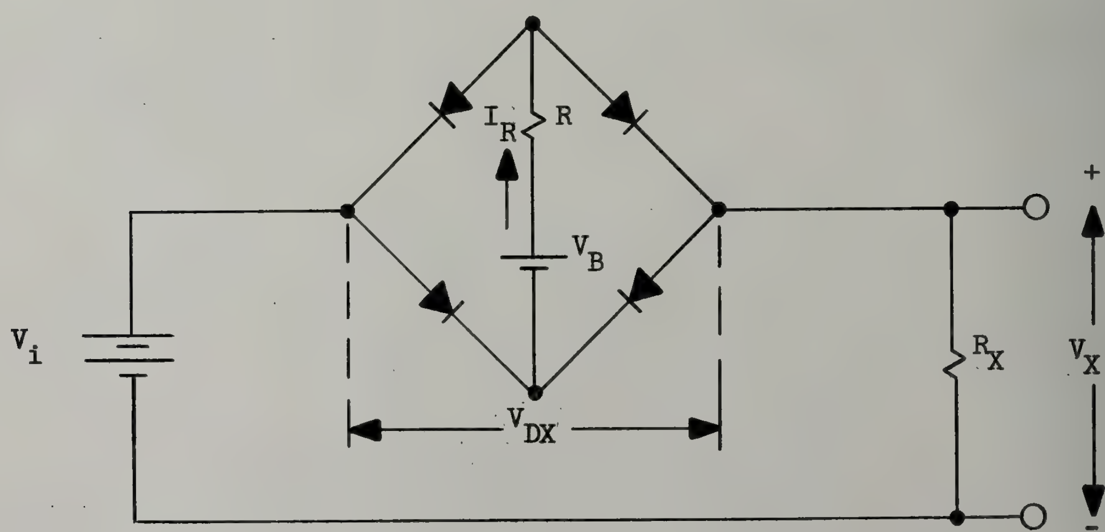


Figure 5 Notation for Bridge Modulator Gate. (Diode: 950. $|v_i| \sim 1.5v$)

The following data were taken:

V_B = 37.3 volts, R = 1K, I_R = 36.2 ma

R_X	V_{DX}	% error $= \frac{V_{DX}}{1.5} \times 100$
∞	-	-
2K	-	-
1K	-	-
470Ω	.02 volts	1.3%
240 Ω	.03 volts	2 %
100 Ω	.08 volts	5 %
51 Ω	.17 volts	11 %

V_B = 19.5 volts, R = 100 , I_R = 36.2 ma

R_X	V_{DX}	% error
∞	.01 volts	.7%
2K	.01 volts	.7%
1K	.01 volts	.7%
470Ω	.01 volts	.7%
240Ω	.02 volts	1.3%
100Ω	.06 volts	2 %
51 Ω	.16 volts	11 %

V_B = 21 volts, R = 1K, I_R = 20 ma

R_X	V_{DX}	% error
∞	0	-
2K	.01 volts	.7%
1K	.01 volts	.7%
470Ω	.02 volts	1.3%
240Ω	.06 volts	2 %

100Ω	.13 volts	9%
51Ω	.40 volts	27%

The data show that the switch voltage is not more than 10% of the circuit voltages as long as the bias current is 20 ma or more, and the load resistance is larger than 100Ω. This low impedance property will allow the switch to be used with small circuit voltages.

PART III

DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. Encoding Scheme for a Class of Patterns

The following file number (DCL #422) was issued this month:

Dr. R. Narasimhan, "An Encoding Scheme of Classes of Patterns with Application to Pattern Recognition Work."

II. Precision 35 mm. Recording Cameras

Two precision electrically advanced 35 mm. recording cameras, as specified in file No. 400 (September 1, 1961) were subcontracted to Flight Research, Inc., of Richmond, Virginia.

III. 105 mm. Scanner-Camera for Scope

A test rig using a 105 mm. K & E camera magazine and a 105 mm. K & E slide projector (scanner) magazing has been completed for the high resolution scope. The 4.4" square scope roster is projected in parallel on the camera and the scanner to cover a 98-120 mm. film frame (effective area of all three views of a 72" hydrogen bubble chamber stereo triad).

R. Narasimhan, B. McCormick

PART IV
ILLIAC USE AND OPERATION

New Illiac Codes

During the month of December, no new routines were added to the Illiac Library.

Illiac Usage

During the month of December, specifications were presented for 15 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2111T. Numbers followed by T are for theses.

2111T Physics. Muon Contamination Computation. The problem is to compute the number of μ mesons arising from π meson decay in flight which will be counted in a magnet-counter system. Specifically, given a source of π mesons and a magnet to momentum analyze the π mesons such that mesons of a proper momentum will be bent into a detector, some μ mesons which result from the decay of π mesons will be able to traverse the system. The amount of the contamination can be calculated by simulating the process using the Monte-Carlo technique. Decays are allowed to occur and the resultant μ mesons are traced through the system and tested for a success or a miss at the plane of the detector.

2112 Mechanical Engineering. The Effect of Prandtl Number on Jet Mixing. The Prandtl Number (P_r) has its direct influence on the stagnation temperature ratio across a constant pressure compressible jet mixing region, which again controls the momentum and energy transfer across such a region.

In particular, it is desired to calculate

$$\Lambda(\eta, c_a^2, P_r) = \frac{t_b}{t_{oa}} + \int_{-\infty}^{\eta} \left(\int_{-\infty}^{\alpha} g(\beta)\, e^{P_r\beta^2} d\beta \right) e^{-P_r\alpha^2} d\alpha$$

$$+ \sqrt{\frac{P_r}{\pi}} \left[1 - \frac{t_b}{t_{oa}} - \int_{-\infty}^{\infty} \left(\int_{-\infty}^{\alpha} g(\beta)\, e^{P_r\beta^2} d\beta \right) e^{-P_r\alpha^2} d\alpha \right] \int_{-\infty}^{\eta} e^{-P_r\alpha^2} d\alpha$$

where

Λ = the stagnation temperature profile.

c_a = the Crocco number.

$\frac{t_b}{t_{oa}}$ = the stagnation temperature ratio across the mixing region.

$$g(\eta) = 2c_a^2 (1-P_r) \frac{d}{d\eta} (\varphi \frac{d\varphi}{d\eta}) .$$

$$\varphi = \frac{1}{2} (1 + \operatorname{erf} \eta) .$$

The integrals

$$\int_{-\infty}^{\eta} \frac{\varphi}{\Lambda - c_a^2 \varphi^2} d\eta, \quad \int_{-\infty}^{\eta} \frac{\varphi^2}{\Lambda - c_a^2 \; {}^2} d\eta, \quad \int_{-\infty}^{\eta} \frac{\Lambda \varphi}{\Lambda - c_a^2 \varphi^2} d\eta$$

and $$\int_{-\infty}^{\eta} \frac{\frac{\varphi^3}{2}}{\Lambda - c_a^2 \varphi^2} d\eta$$ will also be calculated.

2113 Chemistry. Sedimentation Analysis. The research problem is to develop an understanding of ultracentrifuge sedimentation data in the case where dimerization is taking place. If the reaction is

$$2A \underset{k_2}{\overset{k_1}{\rightleftarrows}} B,$$

the concentrations a, b of A and B satisfy (under certain simplifying assumptions) the following partial differential equations:

$$v_A \frac{\partial a}{\partial x} + \frac{\partial a}{\partial t} = -k_1 a^2 + k_2 b,$$

$$v_B \frac{\partial b}{\partial x} + \frac{\partial b}{\partial t} = k_1 a^2 - k_2 b.$$

It is proposed to use Illiac to solve these equations (probably with a straightforward, explicit difference scheme) for several values of the parameters k_1, k_2, v_A and v_B.

2114T Chemistry. Formic Acid Rate Constant. The research problem consists of taking 800 or more experimental results and processing them to provide a number of sets of rate constants. These rate constants characterize the photochemical decomposition of formic acid vapor under a number of conditions.

Each experiment produces five independent variables u_i, w_i, x_i, y_i and z_i. These are related to each other by

$$Au_i + Bw_i + Cx_i + Dy_i + Ez_i = 0$$

where the coefficients are known combinations of rate constants. In order to get a good fit of the points to the curve, a modified least square approach to the problem is used.

2115 Psychology. Interpersonal Perception and Personality Assessment. This project investigates the relationships between various aspects of interpersonal perception and factors related to the individual's personality, background and environment, as well as the consequences of various experimental manipulations of environmental conditions on patterns of interpersonal perception. Major analyses require computation of D-statistics, summations of questionnaire scores, computation of correlational matrices, centroid factor analyses, varimax rotations of factors, computations of means, variances, covariances and analysis of variance ratios.

2116 Psychology. Group Creativity. This project is concerned with factors contributing to creativity in groups, with emphasis upon leader attitudes, abilities of members and leaders, and the effects of various training methods. Major data analyses will require computations of D-statistics, sums, averages, variances, covariances, and analysis of variance ratios, as well as the use of statistical library programs K-8, KSL 120, and KSL 180.

2117 Mining and Metallurgical Engineering. Capillarity and Fluid Flow in Porous Media. Several inter-related problems in capillarity and flow through porous media will be studied. The problems are: experimental data and hydrodynamical models will be analyzed for the dependence of capillary forces on velocity and acceleration; structure analysis of porous media; numerical solution

of the Stokes-Navier equations for boundary situations involving capillarity; solution of electric flow analogues of fluid flow through porous media.

2118 Physics. Effect of λ Transition on Atomic Distribution in Liquid Helium by Neutron Diffraction. The machine will be used to numerically integrate the equation:

$$g(r) = \frac{2\,r}{\pi} \int_0^6 k \sin (k\,r) \left[F^2(k) - 1\right] dk$$

where $F^2(k)$ is tabulated data and the integral is evaluated at 600 points over $k\ (0 \rightarrow 6)$.

2119 Animal Science. Amino Acid Determinants of Feed Efficiency. The effects of various levels of amino acid concentrations (and their interactions) on feed efficiency are to be determined. The analysis of covariance (K-15) is the major statistical technique to be used. Auxiliary programs to prepare data for K-15 are also to be utilized.

2120 Digital Computer Laboratory. Probability Distribution of Partial Remainders. For a given divisor, the problem generates a matrix of transition probabilities for partial remainders. The steady-state probabilities are found by M14.

2121 Chemistry and Chemical Engineering. Atomic and Molecular Energy Eigenvalue Approximations Based on the Consolidated Variation-Perturbation Method. The combined variation-perturbation method used to approximate energy eigenvalues for atomic and molecular systems involves the analytical evaluation of a considerable number of one and two electron integrals, the evaluation of eigenvalues and eigenvectors of small symmetric matrices, the inversion and multiplication of rather large matrices. The integration process involves much looping in order to evaluate the rather complicated analytical expressions which are composed mainly of several summations over products of variable factorial and exponential terms.

2122 Physics. Unfolding Transmission Spectrum to Find Emission and Absorption Spectrum. A transmission spectrum is to be analyzed from measured values of A_v, the intensity at frequency v.

2123 Microbiology. Biological Coding. The set of linear equations

$$Aa + Bb + Cc + Dd = w'$$
$$Ab + Bc + Cd + De = x'$$
$$Ac + Bd + Ce + Df = y'$$
$$Ad + Be + Cf + Dg = z'$$

is to be solved for A, B, C, and D.

a, b, c, d, e, f, g are constant numbers. w', x', y', z' are measured.

The purpose of the computation is to analyze the data on compositional relationship between DNA and protein.

2124 Psychology. Second-Order Personality Factors in Children. Data are available from a previous study on first-order personality factors in children which will be used for this analysis. First, the intercorrelations of the primary factors will be computed, and the resulting correlation matrix factor will be analyzed and obliquely rotated. The main computation time will be used for visual oblique rotations.

This is the first study ever to be done on second-order objective personality test factors in children of the ages 7 - 8 years.

2125 Institute for Research on Exceptional Children. Factor analysis will be carried out on two 30 variable matrices. The first matrix contains husband's domestic values (10 variables), husband's ranking of life goals for boys (10 variables), and husband's ranking of life goals for girls (10 variables). The second matrix contains wife's domestic values (10 variables), wife's ranking of life goals for boys (10 variables), and wife's ranking of life goals for girls (10 variables).

The study from which the data were taken dealt with family values and was obtained from 364 husbands and 367 wives.

Both husband and wife ranked two sets of family values and each sex's response was considered as distinct parts of one study. The method of

mathematical analysis will be as follows: obtain Pearson Product Moment Correlations (KSL 2.01-K8), factor analyze matrices by the Centroid method, use Varimax Rotation to obtain simple structure (KSL 1.80).

Table I shows the distribution of Illiac machine time for the month of December. The figures in parentheses are the times used on the Coordinated Science Laboratory's CDC 1604, using a program which simulates Illiac exactly.

TABLE I

	Hrs:Min	
Scheduled Maintenance	53:38	
Unscheduled Maintenance	3:17	
Drum Engineering	2:01	
Leapfrog	3:15	
Library Development	:32	
Classes	12:07	
Wasted	:07	
Demonstrations	:30	
		75:27

Use by Departments

Aeronautical Engineering	3:39	
Agricultural Economics (APPRAISAL 47-15-05-334)	1:52	
Agricultural Economics	12:35	
Agricultural Engineering	:08	
Animal Science	4:05	(:39)
Astronomy (NSF-G-14834)	3:08	
Bureau of Economic and Business Research	:53	
Chemistry	75:23	(1:10)
Civil Engineering (HIGHWAY BRIDGE IMPACT)	2:13	
Civil Engineering	114:43	(5:37)
College of Medicine	:12	
Coordinated Science Laboratory (DA-36-039-SC 56695)	77:59	
Digital Computer Laboratory (US TR AEC-1018)	7:30	
Digital Computer Laboratory	:17	
Economics (NSFG 7056)	8:04	
Education	:45	
Electrical Engineering (NONR 1834(22))	:41	
Electrical Engineering (NASA-NSG 24-59)	4:34	
Electrical Engineering (NOBSR 64723)	1:29	
Electrical Engineering (AF 33 (616) 6079)	:05	
Electrical Engineering (NSFG 19005)	1:42	
Electrical Engineering (AF 7043)	11:21	
Electrical Engineering	7:27	(:38)

Food Technology (50-343)	4:14			
Inst. of Communications Research (44-28-20-378)	1:19			
Inst. of Communications Research (USPHM-3941)	1:11			
Institute of Communications Research	:13			
Mechanical Engineering (NSG-13-59)	1:34			
Mechanical Engineering	28:16			(:03)
Microbiology	:03			
Mining and Metallurgical Eng. (TRUS AF 6770)	:31			
Mining and Metallurgical Engineering	1:24			
Office of Instructional TV (OE 7-11-107.00)	7:44			
Office of Instructional TV	:24			
Physical Education	:11			
Physics (GEN. ELEC. FELLOWSHIP)	1:30			
Physics (NONR 1834(05)A)	1:31			
Physics (ORD 18)	:09			
Physics (NSF 14 308)	:07			
Physics	15:22			
Psychology (1715)	:23			
Psychology (MD 2060)	:49			
Psychology (AF 41-657-279)	:20			
Psychology (AF 49(638)371)	17:04			
Psychology (USPH 45-32-66-373)	1:19			
Psychology (ONR 46-32-66-362)	:45			
Psychology (M1774)	1:07			
Psychology (ONR 1834-36)	:45			
Psychology	56:19			(6:21)
Sociology	13:54			
State Water Survey	5:01			
State Water Survey (DA-36-039-SC75055)	10:09			
Theoretical and Applied Mechanics (DA-11-070-508)	12:28			
Theoretical and Applied Mechanics (DA-01-021-11878)	1:40			
		528:33		
			604:00	
				(14:08)

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m.

and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III., and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Arithmetic	1
Drum	2
Reader	1
Total	4

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
12/1/61	21:15	:00	2:45	0		:00	:05	0
12/2/61	24:00	:00	:00	0		:00	:48	0
12/3/61	24:00	:00	:00	0		:00	:00	0
12/4/61	20:41	:00	3:19	0		:00	:00	0
12/5/61	18:10	2:38	3:12	1	(1) Arithmetic failure. Solder joint at terminal lug loose.	:00	:00	0
12/6/61	21:21	:00	2:39	0		:00	:00	0
12/7/61	20:36	:00	3:34	0		:00	:00	0
12/8/61	21:57	:00	2:03	0		:00	:00	0
12/9/61	24:00	:00	:00	0		:00	:00	0
12/10/61	24:00	:00	:00	0		:00	:21	0
12/11/61	21:11	:00	2:49	0		:00	:19	0
12/12/61	21:35	:00	2:25	0		:00	:00	0
12/13/61	20:04	:29	3:27	1	(1) Drum failure.	:00	:06	0
12/14/61	20:38	:00	3:22	0		:00	:00	0
12/15/61	21:45	:00	2:15	0		:00	:18	0
12/16/61	24:00	:00	:00	0		:00	:00	0
12/17/61	23:40	:20	:00	1	(1) Light burned out in Reader "B".	:00	:00	0
12/18/61	21:24	:00	2:36	0		:00	:17	0
12/19/61	20:30	:00	3:30	0		:00	:00	0
12/20/61	20:52	:00	3:08	0		:00	:16	0
12/21/61	22:34	:00	1:26	0		:00	:18	0
12/22/61	3:50	:00	:10	0	(Closed down at noon).	:00	:09	0
12/26/61	20:35	:25	3:00	1	(1) Drum failure.	:00	:02	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
12/27/61	20:39	:00	3:21	0		:00	:00	0
12/28/61	21:30	:00	2:30	0		:00	:00	0
12/29/61	21:46	:00	2:07	0		:07	:00	0
TOTALS	546:23	3:52	53:38	4		:07	2:59	0

PART V

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New International Business Machines 650 Codes

During the month of December, no new routines were added to the International Business Machines 650 Library.

International Business Machines 650 Usage

During the month of December, specifications were presented for ten new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 347'. Numbers followed by T are for theses.

347' Civil Engineering. Computation of Underground Structural Response. An iteration procedure is being used to solve a set of n simultaneous non-linear second order differential equations. Atomic blast on the ground gives rise to shock waves propagating in the soil. In order to analyze underground structures, it is first necessary to find the manner in which this shock wave will propagate toward the structure. The shape of the shock wave and the stress-strain characteristics of the soil are known. For purposes of analysis, the mass of the soil is lumped at discrete points. The differential equations governing the motion of these masses are to be solved.

348' Mining and Metallurgical Engineering. Efficiency Determination of Jigs. This program will determine the efficiency of jigs used in coal preparation plants from washability data which is obtained from coal companies. These calculations are being used presently by a jig manufacturer but not on a computer. Hence, this program duplicates these calculations but with a variable set of parameters. After the program has been code checked, it is intended to vary these parameters in order to determine optimum sets of parameters for given conditions.

349' Agricultural Economics. Interregional Flows of Corn. The United States is partitioned into 38 regions. For each of these regions the demand and supply of corn is given. Also the transportation cost between each pair of regions is know. Given these data the problem is to determine the graphical flows of corn which will satisfy the demands in each region and minimize the total cost of transportation.

350' Mechanical Engineering. Processing of Experimental Data from Heat Transfer Test. The following quantities will be computed from the given data V, and I.

$$\Delta T$$

and

$$h = \frac{I^2 \, 19.659}{\Delta T}$$

where T will be given by

$$T = 34.904 \; V + 31.645$$

V (in millivolts), and I (in amperes), are measured on the experimental setup.

This problem is input-output dominated and should run at full input-output speed.

351' Agronomy. Physiology of Soybeans. Soybean varieties are being tested for a differential response to five levels of mineral elements; calcium, phosphorous, iron, etc. These tests are conducted at temperatures of 60°, 70° and 80° F. Analysis of variance is used to determine if the varieties respond the same to the varying levels of mineral elements and temperatures.

352' Civil Engineering. Adjustment of Aerotriangulation. This research project deals mainly with the character of errors in spatial aerotriangulation, and further studies in a new adjustment method, the "Cross-Bases Method".

With the aid of some known, or measured, parameters (model scale, lateral and longitudinal tilt, swing and elevation), a mathematical surface representing the errors in X, Y and Z of any point within the area studied can be reconstructed. Thus, the coordinates and elevations of any desired point can be adjusted. Normally, a statistical analysis of the residual errors is undertaken to determine the accuracy of the adjustment.

353'T Psychology. Conflict and Physiological Arousal. The study involves the comparison of four groups of subjects and their physiological reactions to different conditioning procedures. The IBM 650 will be useful in correlational analysis of the data. The specific interests in the correlational analysis are in determining functional relationships between three physiological measures (heart rate, skin conductance and palmar sweating) and to further determine idiosyncratic patterns of autonomic arousal which exist within subjects under various conditions.

354'T Institute of Communications Research. Army Study. The research problem involves examining the association between aggregated measures of opinion climates and soldiers' responses in the area of army food ratings in a sample of U. S. Army units. The data to be analyzed consists of responses from a survey of soldiers in seven U. S. Army installations pertaining to opinions of the Army, its officers and its food as these relate to longevity, career plans, and civilian background of the troops. Computation of means on relevant scores, followed by multiple regression and correlation analysis, is proposed.

355' Physics. Tunneling Curves. Values of

$$\int_0^\infty dx\, e^v \frac{g(x)}{\left[g(x) + e^v\right]^2},$$

where

$$g(x) = e^{\sqrt{x^2 + \Sigma^2}}$$ will be computed.

This is to be done for one value of Σ and approximately 20 values of v. This yields a theoretical curve for the differential conductance of a thin insulating barrier located between a normal metal and a superconducting metal with a gap width equal to Σkt at voltage vkt, where t is the absolute temperature and k is Boltzmann's constant.

356' Speech and Theatre. Symbol Constancy and Equivalence. An application of the semantic differential is used with a group of normal hearing adults to measure the constancy and equivalence of symbols representing certain concepts.

A 3 x 10 x 10 split-split plot randomized complete block design with ten replications is used. The 650 will compute analysis of variance for the three factors and their interactions separately for two sessions of the experiment, for the sessions combined and for the difference between the two testing sessions. It will also be used to make 29 single degree of freedom comparisons on the factors involved in the study.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of December.

TABLE I'

		Hrs:Min	
Scheduled Engineering		12:37	
Unscheduled Engineering		5:11	
Air Conditioning		1:10	
Tape Test		:06	
Computer Operator		:24	
Log Summary		:27	
Library Development		20:28	
Agronomy Library	7:04		
DCL Library	13:24		
Classes		96:06	
CE	29:09		
EE	1:58		
MATH	61:26		
ME	3:33		
Instruction		:42	
Wasted		3:32	
			140:43

Use by Departments

Agricultural Economics	:38
Agronomy	23:18
Chemistry	8:55
Civil Engineering	14:28
Coordinated Science Laboratory	2:41
Electrical Engineering	20:58
Mechanical Engineering	3:55
Mining and Metallurgical Engineering	:33
Physics	:14
Small Homes Council	1:33
State Water Survey	8:26

Statistical Service Unit		94:00		
Agricultural Economics	2:38			
Bur. of Community Planning	12:15			
Bur. of Educational Research	3:55			
Bursar's Office	10:23			
Business Office	12:25			
DHIA	40:26			
Education	4:02			
Inst. of Communications Research	:09			
Mining and Metallurgical Eng.	1:53			
Physical Education	3:48			
Psychology	:30			
Statistical Service Unit	1:36			
Theoretical and Applied Mechanics		:46		
			180:25	
				321:08

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for December.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

533 card read punch		1
Card jam	1	
652 and 727 tape units and tape control		2
Reads tape incorrectly	1	
Vacuum doesn't break	1	
407 accounting machine		5
Prints incorrectly	1	
Card jam	1	
Fuse	2	
Spills paper	1	
650 console and magnetic drum		10
Program register loses or picks up bits	7	
Fuse	2	
Distributor has both signs	1	
TOTAL		18

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
12/1/61	16:57			:20	3		(1) Lost quinary bit in pos. 3 of program register. (2) 407 printed incorrectly. (3) Tape reading errors on unit 3.
12/4/61	14:16	2:06	(:40)*	:00	1		(1) Card jam on 407 due to a broken latch.
12/5/61	16:03		(1:00)* :12	:10	1		(1) Vacuum does not break in tape unit 3. Found two bad tubes.
12/6/61	16:35			:14	0		
12/7/61	15:17		2:19	:06	3		(1) Fuse blew. Found drum was getting too much oil due to faulty circuit.
12/8/61	19:48			:16	0		
12/11/61	12:00	3:52		:07	0		
12/12/61	16:01		:05	:06	3		(1) Double sign in distributor. (2) Fuse blew in 407. (3) Lost quinary bit in pos. 3 of program register.
12/13/61	15:11		:27	:18	1		(1) Multiple bits in pos. 1 of the program register. Reason unknown. Did not repeat.
12/14/61	16:01			:12	0		
12/15/61	15:14		:56	:19	1		(1) Multiple bit in positions 1 and 2 of program register. Reason unknown. Did not repeat.
12/18/61	13:43	2:42		:00	0		
12/19/61	16:08			:08	0		
12/20/61	16:21			:08	0		
12/21/61	15:47		:18	:24	1		(1) Multiple bits in program register five times in various positions.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
12/22/61	4:07			:03	0		
12/26/61	12:28	3:57		:00	1		(1) Fuse blew in 407.
12/27/61	16:12		:05	:07	2		(1) Program register, multiple bits in pos. 1. (2) Card jam in 533 read feed.
12/28/61	14:11		:49	:21	3	1:10	(1) Program register, multiple bits in positions 1, 2, 4. Trouble disappeared. (2) Main fuse blew on 650 in chassis 7. (3) 407 spills paper. Paper tape in backwards.
Totals	298:38	12:37	5:11	3:32	18	1:10	*Engineering done on some unit but 650 was continuing to operate properly. This is not included in the totals.

PART VI

INSTRUCTIONAL USE OF COMPUTERS

During the month of December, specifications were presented for 12 new problems.

23 Mathematics 195. Problem 6. IBM 650. Solution of an Equation. Locate the positive solution of the equation

$$5X - \sin X - 5 = 0$$

(X in radians) by the method of simple iteration. Put the equation into the form

$$\sin X = 5X - 5.$$

Draw curves for

$$y = \sin X$$

$$y = 5X - 5$$

to locate the initial approximation.

Write a GAT program to do the simple iteration.

Use the following criterion for stopping the iteration

$$5X^* - \sin X^* - 5 < 10^{-6}$$

where X^* is the approximation to the solution found by the iteration method.

To illustrate the convergence toward the solution print X^* and $y = 5X^* - \sin X^* - 5$ after each iteration.

Then, locate the real, positive solution of

$$X^3 - 2X - 5 = 0$$

by Newton's method.

Use the following criterion for stopping:

Require that

$$|\Delta X^*| < 10^{-6}$$

where X^* is the correction to the approximation X^*, i. e.,

$$\Delta X^* = - \frac{f(X^*)}{f'(X^*)}$$

Write a GAT program to do this computation.

To illustrate the convergence toward the solution print X^* and $f(X^*)$ after each iteration.

24 Mathematics 365. Problem 1. Illiac and IBM 650. Term Problem in Mathematics 365. Each graduate student in the course has been assigned the term problem of programming for either computer a large problem from his own field.

One problem will be on the Illiac and will be largely one of matrix manipulation for special uses. This problem is largely psychological.

The other will be on the 650 and will involve considerable use of the tapes. This problem is concerned with power company distribution systems.

25 Mathematics 295. Problem 1'. IBM 650. Solution of an Equation. The equation

$$x^3 - 15s + 22 = 0$$

will be solved by two iterative methods. Newton's method and the method of successive substitution will be used.

26 Industrial Engineering 283. Problem 1. Illiac. Linear Programming. Each student made up and solved by hand a linear programming problem based on a semester laboratory problem.

These will also be solved on the machine.

27 Electrical Engineering 349. Problem 1. IBM 650. Isocline Method. The problem is the solution of the differential equation

$$\ddot{x} + \epsilon\,(1-x^2)\,\dot{x} + x = 0$$

by graphically choosing values of

$$\frac{d\dot{x}}{dx}$$

and $x \doteq f(\epsilon)$, plotting the locus of constant

$$\frac{d(\frac{1}{x})}{dx} = \frac{x}{\epsilon - m - x^2}\ .$$

Three equations are to be solved for three values of ϵ. Each solution requires the plotting of curves for several values of m from y = -4.4 to y = 4.4.

28 Electrical Engineering 320. Problem 1. IBM 650. Y(RL || C). Find the frequency response for a R-L in parallel with C circuit for various values of normalized resistance, r, and reactance, λ.

$$\bar{y} = \frac{r}{r^2 + \lambda^2} + j\lambda \frac{r^2 + \lambda^2 - 1}{r^2 + \lambda^2}$$

$\lambda = 0(.2)5.0$

$r = .2(.2)3.0$

29 Sociology 485. Problem 1. Illiac. Comparison of Factor Analysis Techniques: Family Data. The class problem has two basic aspects: to allow the student to become acquainted with the setting up, analysis and interpretation of data using the factor analytic technique and to acquaint the student with the general method of processing factorial data on Illiac and more specifically to introduce him to particular factorial and rotational techniques.

The students will compare their results obtained through centroid and principle axis factor analysis, varimax versus oblique rotation of centroid factors, and estimations of communalities versus unities in centroid analysis.

The data to be used will consist of 14 scales on judgment of adequacy of the American family which was completed by 80 students. The data were gathered for this class problem.

30 Nuclear Engineering 490. Problem 1. Illiac. Reactor Kinetics with Linear Temperature Coefficient. The reactor kinetics equations for six groups of delayed emitters, including a linear temperature coefficient of reactivity, are a set of nine differential equations (ordinary, linear, inhomogeneous, non-constant coefficients). The variables are time, neutron density, six precursor concentrations, and temperature.

The reactivity is to be changed according to a sine law, starting from a steady state operation.

The solution is to be obtained by stepwise integration, using routine F6-239.

A parameter study is to be made (nine different parameters).

31 Civil Engineering 391. Problem 4. IBM 650. Term Papers. Graduate students taking CE 391 for one unit credit are required to submit a term paper. Several of these students are developing short programs or subroutines which can be coded and checked during the time available. Since these are individual problems, no general descriptions can be given at this time.

32 Mathematics 295. Problem 2'. IBM 650. Least Squares Fit. You are to do a "least squares" fit to the equation

$$y_i = a + bx_i$$

for the parameters a and b.

The (x_i, y_i) are an unknown number--say N, pairs of quantities $(N \leq 100)$. The "least squares" fit is the set of a and b that minimize

$$\chi^2 = \sum_{i=1}^{N} \left[y_i - (a + bx_i) \right]^2 .$$

To find the minimum, we differentiate with respect to a and b and equate to 0.

Thus

$$-2 \sum_{i=1}^{N} \left[y_i - (a + bx_i) \right] = 0 = \frac{\partial \chi^2}{\partial a}$$

$$-2 \sum_{i=1}^{N} x_i \left[y_i - (a + bx_i) \right] = 0 = \frac{\partial \chi^2}{\partial b} .$$

Writing

$$Y = \sum_{i=1}^{N} y_i \qquad X = \sum_{i=1}^{N} x_i$$

$$R = \sum_{i=1}^{N} x_i y_i \qquad V = \sum_{i=1}^{N} x_i^2$$

we have

$$Y = aN + bX$$
$$R = aX + bV .$$

Thus $$a = \frac{YV - RX}{NV - X^2} \qquad b = - \frac{YX - RN}{NV - X^2} .$$

Each x_i and y_i are punched in fields 1 and 2 of a standard 650 data card. The last card of a set (the Nth) has a non-zero word in field 3.

Your program must read these in and find N, and be able to obey a second set of data when it has finished. Print the results on the 407 with a in the first field and b in the third.

Use the high speed storage for the sums above. Read all cards before starting the calculation. Use floating point. Use index registers. Use SOAP and condense the resulting deck.

33 Mathematics 195. Problem 9. IBM 650. Homework 9. Write a GAT program to solve the following set of five simultaneous linear equations.

$$\begin{aligned}
6x_1 + 4x_2 + 3x_3 + 5x_4 + 17x_5 &= 473 \\
-7x_1 + 5x_2 + 2x_3 - 8x_4 + 11x_5 &= 127 \\
11x_1 + 13x_2 + 2x_3 - 7x_4 + 9x_5 &= 243 \\
16x_1 + 3x_2 + 8x_3 + 4x_4 + 5x_5 &= 260 \\
-2x_1 + 7x_2 + 7x_3 - 9x_4 + x_5 &= -70
\end{aligned}$$

Use the Gauss Algorithm to triangularize this system of equations, followed by back substitution to obtain the solution.

Print the solution x_1, x_2, x_3, x_4, x_5 and the residues y_1, y_2, y_3, y_4, y_5. The residues are obtained by substituting your solution into the original set of equations and subtracting the left side of the equation from the right side. Thus y_1 is given by

$$y_1 = 473 - (6x_1 + 4x_2 + 3x_3 + 5x_4 + 17x_5)$$

and similarly for y_2, y_3, y_4, and y_5. Of course, the residues should be zero, but because of round-off errors your solution will not, in general, be exact and the residues may be slightly different from zero.

34 Chemistry 428. Problem 1. IBM 650. Indexing a Crystal. The lattice constants of an unknown crystal are to be determined and the crystal indexed. The computer is used to determine possible d-spacings given the lattice constants a, b, c, cos β and the wave length λ of the radiation. The information supplied by this will give the exact lattice constants, and the exact indexing of all lines appearing on a diffraction pattern.

PART VII

GENERAL LABORATORY INFORMATION

Seminars

"Kinematic Fitting of Bubble Chamber Data by Least Squares Analyses", by Mr. Peter Berge, Lawrence Radiation Laboratory, Berkeley, California, December 4, 1961.

"The Illiac Simulator for the CDC 1604 Computer", by Professor Wayne W. Lichtenberger, Coordinated Science Laboratory, University of Illinois, December 11, 1961.

"Input-Output System for the New Illinois Computer", by Dr. Christopher S. Wallace, Digital Computer Laboratory, University of Illinois, December 18, 1961.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	12	2	13.0
Research Associates	7	0	7.0
Graduate Research Assistants	12	19	22.1
Graduate Teaching Assistants	0	3	1.5
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	41	13	46.66
TOTAL	79	37	97.26

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors, H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith and J. N. Snyder.

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